PREDICTING THE MESIAL-DISTAL DIMENSIONS OF TEETH WITH PANORAMIC RADIOGRAPHY

By

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INTRODUCTION

John Hunter[1] in 1771, after extensive investigation which revealed the sites of new bone growth, wrote the historical masterpiece, "On the Natural History of the Human Teeth." He concluded:

> The jaw still increases in all points till twelve months after birth, when the bodies of all six teeth are pretty well formed; but it never after increases in length between the symphysis and the sixth tooth; and from this time, too, the alveolar process, which makes the anterior part of the arches of both jaws, never becomes a section of a larger circle, whence the lower part of a child's face is flatter, or not so projecting forwards as in the adult.
>
> After this time the jaw lengthens only at its posterior ends................

Since his contribution, growth studies have been prolific but many questions remain unanswered and the clinician is frequently confronted with a dilemma in diagnosing occlusion during the developmental stages. Factors such as facial growth, muscular force, and other physiological, hereditary, and pathological processes acting concurrently cloud the picture.

For evaluating the alignment of the dentition, Strayer[2] has recommended the use of patient history, dental history of parents and grandparents, periapical radiographs, cephalometric headplates, study models, photographs, and the clinical examination. The mixed dentition analysis has also emerged as a helpful tool for diagnosis.

The purpose of this study was to determine the relative accuracy of a panoramic radiographic method in quantitatively recording the mesial-distal diameters of unerupted teeth: a necessary step in the mixed dentition analysis.

REVIEW OF LITERATURE

This review will deal first with the mixed dentition analysis, next with the development of laminographic radiography and its relationship to the mixed dentition analysis, and finally with the distortion encountered in plane and curved surface radiography.

The Mixed Dentition Analysis

G. V. Black[3], after measuring many casts, reported in 1902 that the primary mandibular cuspid, and first and second primary molars were on the average 1.7 millimeters larger per quadrant than their successors. From a sample of fifty-three models which had been taken serially by a group of orthodontists, Northcroft[4] observed that the primary molars were approximately 33 per cent smaller than their successors.

Nance[5] also observed a differential between primary and permanent tooth mass and he labeled this difference "leeway" which he, like Black, found to be 1.7 millimeters per mandibular quadrant and slightly less than one millimeter in the maxillary quadrant. Nance devised a mixed dentition analysis comparing the mesial-distal measurements of the erupted teeth at their greatest convexity from a model with the mesial-distal widths of the unerupted teeth from radiographs. The mesial-distal dimensions of the permanent teeth anterior to the permanent first molars were totaled. To determine arch length, a brass ligature wire was formed on the model from the mesial of the left first permanent molar around the dental arch at the middle one-third of the buccal and labial surfaces of all the teeth to the mesial of the right first permanent molar. After subtracting from the total arch length the "leeway," which Nance realized was taken up by the mesial migration of the first permanent molars, arch length adequacy or inadequacy could be predicted. He recognized the weakness of the radiographic measurement, particularly if a meticulous radiographic technique was not followed. He decided that radiographic distortion was not significant if the central ray passed directly through the contacts and overlapping of the teeth was avoided.

Ballard and Wylie[6] determined, after measuring the casts and radiographs of 441 individuals, that there was a positive correlation between the size of the mandibular incisors and the size of the unerupted tooth mass. A formula was devised to predict the sum of the unerupted tooth mass:

$$X = 9.41 + 0.527Y$$

where X = the sum of the cuspid and first and second premolars of one side of the mandibular arch

Y = the sum of the four mandibular incisors

The mandibular permanent first molar with the incisor dimensions did not improve the prediction of the unerupted tooth mass significantly. Thus its dimension was not included in the correlation formula. A predictive graph was devised to replace radiographic determination of the size of the unerupted teeth and incorporated into the mixed dentition analysis.

Arithmetic computation revealed the error of the predictive graph to be 2.6 per cent as compared to 10.5 per cent when the sizes were determined from periapical radiographs, as advocated by Nance.

Greiwe[7] observed a similar correlation between the total mandibular incisor width and the cuspid, first and second bicuspids of the maxillary arch and mandibular arch. In his sample of 219 orthodontic patients, a positive correlation existed between total incisor widths and the combined widths of the cuspid, first and second bicuspids, in each arch.

Ten years later, Foster and Wylie[8] reevaluated the results of the predictive graphs of Ballard and Wylie as compared to radiographic results in tooth mass prediction. They concluded that the mesial-distal dimensions of the unerupted cuspid and bicuspids could be determined with greater accuracy from periapical radiographs than from mathematical formulas, if the radiographs were made with a meticulous technique.

Carey[9] evaluated linear arch dimension and tooth size in an effort to determine when tooth extraction was beneficial in creating a complementary arch length and tooth mass. He based his study on patients he had treated over eighteen years of orthodontic practice. Basal bone deficiency was determined by measuring with a brass wire the linear dimensions over the buccal cusps and over the anterior ridge and comparing his total with the sum of the mesial-distal diameters of the teeth. A formula was proposed:

$$LA + 2X + 3.4 = L.D.$$

where LA = sum of the lower anterior teeth

X = estimated size of the unerupted cuspid and premolars

L.D. = linear arch dimension

Carey designed a clinical calculator with which he could quickly determine the size of the unerupted cuspids and bicuspids.

An index was formulated by Pont[10] after measuring thousands of "perfect cases." His philosophy of orthodontic treatment involved extracting primary teeth only to maintain symmetry, and the premolars were never removed. A correlation was determined between the widths of the upper four incisors and the ideal distance needed between the distal pits of the upper left and right first premolars and the distance between the central fossae of the upper left and right first molars. Premolar and molar indices were computed and the following formulae devised by Pont to determine the intermolar and interpremolar widths to which the treatment was to be extended. The formulae:

$$\frac{X \times 100}{80} = Y$$

X = widths of the maxillary permanent incisors (mm)

Y = distance in millimeters of the first premolars required

$$\frac{X \times 100}{64} = Y$$

X = widths of the maxillary incisors

Y = desired intermolar width

64 = molar index

The curves of Spee and Wilson were important considerations in the Pont analysis. The curve of Wilson determined arch width and the curve of Spee determined the vertical dimension.

Hixon and Oldfather[11] found a more accurate technique for estimating tooth mass in their investigation of 76 individuals. An intraoral measurement of the mandibular central and lateral incisor was summed with the dimensions of the two unerupted bicuspids deteremined from a radiograph. The diameter of the cuspid and bucuspids was finally estimated from a correlation chart. A 16-inch cone was required in their technique and a total increase in accuracy of 25 per cent was demonstrated over the Nance and Ballard Wylie analyses.

Moyers[12] also devised a chart for determining the mesial-distal size of the unerupted teeth. His chart, however, includes per cent probability of error in the technique so that the clinician is aware of the exact degree of inherent inaccuracy. Unique to Moyers' analysis is the prediction of maxillary tooth diameter as well as mandibular.

To date the literature does not contain a technique of laminographic radiography which reduces the linear distortion sufficiently to predict the unerupted tooth mass with minimal inaccuracy. The remainder of this review is directed toward this problem.

Laminographic Radiography

Jean Kieffer[13], an American, was one of the first investigators to describe the principles of planigraphic or laminographic radiography. He patented his idea in 1929, but could not convince his colleagues at the University of Washington to build a prototype machine until 1936. Unknown to Kieffer, two other groups headed by Bocage[14] and by Portes and Chause[15] had been working independently and had obtained French patents in 1922 based on similar principles.

Not since 1895, when physicist Wilhelm Roentgen produced electromagnetic radiation in a partial vacuum by the discharge of electrons against a target, has radiology changed significantly in application. The quality of the radiographs made in the first tests of Kieffer's machine were so promising that it was put into immediate use. His prototype was built horizontally along a linear tract. Kieffer states:

> The fundamental principle of planigraphy is that the tube and film move during exposure in such a way that the roentgenographic shadow of a selected plane in a body remains stationary on the moving film while the shadows of all other planes have a relative displacement on the film, and are therefore blurred to varying amounts, depending mainly on the distance of such planes from the one selected.

He showed that "the character and appearance of the blurring depend on the amplitude of the motion and on the distance of the target and film from the plane visualized or, more generally, on the angle subtended by the travel of the target at a point on the plane visualized." He found that rectilinear motion resulted in unsymmetrical blurring which introduced marked distortion. On the other hand, circular or spiral motion resulted in symmetrical blurring and therefore would be better for the elimination of superimposed shadows caused by relatively small or complex structures, such as are found in the head.

In 1948 Yrjo Paatero[16], wanting to design a simpler method for full mouth radiographic examination, pioneered the use of laminography in dentistry. He referred to his technique as tomographic radiography. To avoid magnification, he intended always to direct the radiation perpendicular to the alveolar process. He realized, however, that rotating the patient or radiation source around one axis would result in decreased dimensions of the anterior teeth which lie on a short radius. He decided that magnification in this region was insignificant for diagnosis. He placed the radiographic film intraorally, maintained a stationary radiation source, and rotated the patient during the exposure. By passing the roentgen rays through a slit, magnification could be virtually eliminated in a vertical direction through the parallelization of the x-rays through the object to the film. Although his equipment was somewhat crude and involved manually revolving the chair during the exposure, he nevertheless was successful in obtaining films of promising quality.

Paatero had followed the essential conditions of this type of radiography in that the image of the object that passes through a beam of x-rays must fall on a film that is moving at the same velocity. He also showed that this synchronization of the image and film was possible by rotating the subject and film in opposite directions.

Nelson and Kumpula[17] in 1955 designed a panoramic machine which also involved intraoral film placement but the source was rotated only when the buccal segments were radiographed and the patient was rotated during the exposure of the anterior segment.

The need for a simple and rapid method of recording dental conditions of large numbers of servicemen led Hudson[18], in cooperation with the National Bureau of Standards, to develop another panoramic machine. Preliminary studies were made to determine geometric relationships and factors influencing projection of images of the desired mouth structures.

Figure 1 is a diagramatic representation of the geometrical arrangement of the panoramic machine and is useful in describing Hudson's data and the geometrical basis of his apparatus. The rate of linear motion of the x-ray source varies with the change in the curvature of an "average" dental arch. The molars and bicuspids lie on the circumference of a circle whose radius, r_T , is slightly shorter than that of a circle whose circumference passes through the incisors and cuspids. The center of both circles is the center of rotation, R. The function of the cam is to synchronize the linear velocity of the film and the velocity of the projected image onto the film. The sharpness of the image is proportional to SF tan which is one-half the slit width. The slit must be sufficiently narrow to provide a sharp image and at the same time be wide enough so that shadows of structures not on the dental arch will be blurred and not interfere with the desired images.

These investigators have developed four techniques which provide a panoramic view of the paraoral structures on a single radiograph. Three procedures use the principle of curved-surface laminography in which the images of structures in a selected plane are recorded. The images of intervening structures are grossly distorted and blurred. The fourth procedure uses an intraoral source of radiation which projects the images onto a film positioned on the patient's face. These ideas are incorporated into four machines now being used.

The Rotagraph was the first of these to be developed. This method has a stationary radiation source and the patient and film rotate around a single axis. The linear velocity of the film is adjustable to conform to the shape of the patient's dental arch. The Panorex technique, developed by Hudson, employs a stationary head position and a radiation source and film which rotates around two axes. The Orthopantomograph also has the patient remain stationary while the source and film rotate around three axes of rotation. The Panagraph uses an intraoral radiation source which projects the images of the teeth to a film which is fitted to the patient's face.

Updegrave[19] cites the simplicity of operation of panoramic radiography as an advantage to the patient and operator. The patient does not have the discomfort or inconvenience of intraoral film placement. Surveys are more readily obtainable on people who tend to gag, on children, on those who have anatomic abnormalities, and on those who are partially or completely edentulous. The operator obtains the survey without changing tube angulation or adjusting the timing during exposure. Further, a more complete outline of oral and paraoral structure is recorded on a single film. Elimination of the superimposition of intervening structures is especially helpful in diagnosis. The continuity of the dental arch can be understood by the patient, so that the Panorex film can be used as a visual aid in case presentation. Finally, and perhaps most importantly, the patient receives less gonadal radiation.

Hudson et al[18,20,21,22,23,24] have concluded that panoramic radiographic examination exposes both patient and operator to less radiation. Hudson used a wax phantom of the human head and measured the ionizing radiation produced at various points during a complete mouth survey obtained with the panoramic method and a conventional fourteen film series survey. The highest levels of radiation using the conventional technique were to the skin of the cheek and the thyroid gland where 23-27 roentgens were recorded. The highest level using the panoramic method was to the cervical lymphatic region of the neck and was 0.42 roentgens.

Kuba[25] calculated that the maximum dose received by the patient during a Panorex examination was less than one roentgen. He also estimated that an operator could make over 3000 films per week without exceeding the limits set by current radiation protection guides.

Disadvantages and limitations also exist with the panoramic techniques. Intensifying screens and an increased object-film distance present in the procedure decrease the definition of individual structures. Certain areas are not well reproduced and the units are bulky and expensive. As with all radiographic techniques, there is distortion and magnification.

Plane and Curved Surface Radiographic Distortion

Early investigations of plane surface radiographic distortion were conducted to determine the relative size of the heart. Albers-Schonberg[26] applied the principles of optics to the roentgen ray to determine heart size. Using the method of similar triangles, the object size can be obtained by direct proportion, if its distance from the film or target is known. The relation is:

$$\frac{\text{Object size}}{\text{Image size}} \qquad \frac{\text{Target-object distance}}{\text{Target-film distance}}$$

Bardeen[27] used an anode-film distance of two meters and attempted to standardize the distortion and develop a usable chart for determining the relative size of the heart. He found a percentage of enlargement or magnification that was approximately equal to one-third the anterior-posterior diameter in centimeters of the chest in expiration. For example, with a chest of eighteen centimeters, the magnification was six per cent. From this value, he determined the average volume of the heart and related this to the normality for that individual.

An investigator named Ciesynski, otherwise unidentified, in 1907 developed the rule of isometry which governed the vertical angulation of the radiation source in relation to the intraoral film packet placement. Even using the bisecting principle which Ciesynski devised for conventional radiography, he concluded that no set rules could be followed since patient size and arch form vary.

In 1920, McCormack[28] suggested a focal film distance of 36 inches to overcome distortion and minimize enlargement. His pioneering procedures only emphasized the difficulties encountered in standardizing radiographic procedures. The fundamental deterrent to the establishment of a single technique for achieving correct tube angulation is the fact that x-rays are divergent. Intraoral radiographs are particularly difficult to standardize. The x-ray beam is limited to two movements: a vertical movement which controls the longitudinal dimensions of the resulting image (to prevent elongation and foreshortening), and a horizontal movement which controls the anteroposterior dimensions (to prevent overlapping of one tooth shadow over another).

Attempts to overcome the inherent distortions produced when divergent light rays must be used to produce a shadow picture have resolved into two philosophies: parallelling and bisecting. Each philosophy has its advantages and disadvantages which have been summarized by Kasle[29].

With the parallelling principle, the film is positioned parallel with the long axes of the teeth and the central ray is directed perpendicular to both the film and the teeth. A neccessary adjunct to this principle is the use of an increased target-to-film distance, for the following two reasons: (1) to prevent magnification of the image, and (2) to prevent blurring of the image border.

In many areas the anatomy of the mouth prevents close parallel approximation of film to tooth, for the film would not then extend as far as the apex of the tooth. Placement of the film to cover the entire tooth requires moving the film away from the teeth toward the midline. To compensate for this increased object-film distance, an increased target-film distance is neccessary.

With the bisecting technique, the tube head and film are positioned after consideration of the geometric theorem which states that two triangles are equal when they have two equal angles and a common side. The angle formed by the mean plane of the tooth and the mean plane of the film is bisected and the central ray is directed through the apex of the tooth perpendicular to the bisecting plane. This creates two equal triangles in which the length of the image on the film equals the length of the tooth. By directing the rays halfway between these two planes so as to be perpendicular to the bisecting plane, we obtain a longitudinal image which is nearly accurate in dimension.

Conventional radiographic images are composites of many superimposed tissue layers, and there are anatomical limitations in film packet placement which produce distortion. Blackman [30] observed that anatomical considerations may make close apposition of the film packet impossible and the contour of the region, other than a geometrically flat contour, prevents the axes of film and object from being parallel to each other. These two complicating factors, i.e. superimpositioning of structures and distortion, are minimized in panoramic radiography.

Adams [31] states that three properties determine the quality of diagnostic radiographs: proper contrast in density, sharpness of detail, and degree of distortion of figure.

Inherent distortion in the panoramic type of laminography was indeed recognized by Paatero [32]. He attempted to reduce magnification by producing, as nearly as possible, an orthoradial projection of each detail in the focused plane and by controlling the dimensions of the radiation beam. Superimpositioning is partially rectified in a curvilinear type of laminography. Structures which are not in the focused plane and which are at right angles to the radiation source are blurred. Unfocused structures which are parallel with the radiation source are elongated and not visible on the film.

The plane in focus is only that portion where the image is moving at a speed that is constant with the movement of the film. In the Panorex machine this plane is 5 3/4 inches high and 1/2 inch thick . Structures lying outside this plane are, in all practicality, removed from the radiographic image.

Knight[33] effectively demonstrated normal anatomic landmarks on the Panorex radiograph by means of a dry skull and radiopaque markers, such as wires, lead, B-B shot, and barium sulfate.

Turner[23] observed that the panoramic view displayed the relative positions of the unerupted teeth, as well as the course and inclination of their roots, better than the periapical projections. The intraoral views, on the other hand, more accurately portray the size of the crowns and the presence or extent of cystic areas about the crowns.

Diers[34] observed that the greatest variation in the axial inclinations was in the second molar region and the least in the first bicuspid region. The largest negative distortion was noted in the lower right cuspid area, with the least negative distortion in the maxillary left cuspid area. The largest positive distortion was in the mandibular right second molar area, with the least positive distortion in the lower left first bicuspid region.

Both negative distortion, where the radiographic image is smaller than the actual object, and positive distortion, where the image is larger than the object, are produced with the Panorex machine.

Kite[22] observed that the object, if not on a plane tangential to a concentric arc, will demonstrate negative distortion and the image size will finally reach zero when the plane of the object coincides with the radius of a circle. At this point the object is parallel with the x-ray source and absolute superimposition occurs.

A dimensionally true image is formed only when the object is sufficiently eccentric to the beam to compensate for the object-film enlargement caused by the divergence of the x-rays.

The rotational synchronization of the film and source in relation to the patient has been designed in the Panorex to accommodate the patient who has an average dental arch. Variations in arch form and size among patients will result in image distortion.

Blackman[30] noted that the configuration of the face varies not only between individuals, but also between child and adult. With the child the contour of the dental arch is more nearly that of a circle, while with the adult the contour is more elliptical. For this reason, more accurate anatomic results could be obtained in the young patient with the panoramic technique. The Panorex is equipped with two cams which can be adjusted to control the lateral width of the field in focus and therefore to accommodate either the child or adult patient.

Distortion is also increased by the fact that the beam is not always perpendicular to all the body tissues. The machine is designed so that the central ray is directed at the film perpendicular to the horizontal axis and at a minus 5 degree angle from the vertical axis. The minus 5 degrees is incorporated into the apparatus so that the central ray is more nearly perpendicular to the long axis of the lingually tilted lower posterior teeth and the buccally inclined upper posteriors.

Improper patient positioning, asymmetry of the dental arches, and movement by the patient during the exposure are the primary causes of distortion.

Langland[35] positioned the patient with the occlusal plane parallel with the floor. He observed that if the occlusal plane was positioned upward from the parallel position, the image of the hard palate was projected over the apices of the maxillary teeth. If the occlusal plane was positioned downward from a parallel position to the floor, the mesial-distal surfaces of all teeth became narrowed and their relationships were crowded.

Kraske and Mazzarella[20] noted that an upward tilting of the occlusal plane caused the loss of the temporomandibular joint image and a blotting out of the apices of the maxillary teeth due to palatal vault superimposition. Overlapping of proximal contact areas was observed in all quadrants of the mouth but most frequently in the upper left premolar region.

The clinical opinion of Laney and Tolman[36] was that the necessity for serial extraction to enhance an orthodontic treatment result could be ascertained from a panoramic film. On the other hand, Kite and associates[22] studied the linear distortion on Panorex films by using metallic screens and wires sealed in polyethylene tubing and adapted to the alveolar mucosa from molar to molar. The wires were calibrated to 0.5 to 1.0 cm. intervals. Their investigations showed an image distortion and enlargement ranging from 6 to 17 per cent depending on the head placement. Kite demonstrated statistically that Panorex films could not be measured directly without a correction factor to obtain quantitative mesial-distal measurements of teeth. The magnification was not uniform and ranged from a negative value in the central incisor region to a two-fold increase in the linear dimension in the third molar area. A simple proportion therefore would not give the operator a true quantitative value of an anatomic structure.

Yamane and Biewald[37], using 1.0 mm. wire bent to simulate a symmetrical mandibular arch with soldered 0.5 mm vertical posts, found that as the distance between the terminal ends of the wire (bigonial width) increased, the first molar region showed the greatest percentage of distortion while the greatest variation in distortion was in the area of the third molars. A more posterior positioning of the arch resulted in considerable fluctuation in the percentage of distortion in the area corresponding to the premolars. These investigators also noted that the left premolar enlargement was often greater than the right, which points out the importance of careful factory installation so that the midline of the unit is properly positioned.

Bruggemann[38] measured the vertical and linear distortion on processed Panorex films using 0.20 mm lengths of 0.035 gauge wire in dry skull material and wax bites of patients. With varying head positions the vertical dimensions remained fairly constant, but the linear measurements varied greatly. There was a change from negative distortion in the central region toward zero and then to a positive distortion in the molar region.

Updegrave[19] placed wood screws in the sockets of the teeth of human skulls and studied distortion with the Panorex. He noted a linear distortion related to the occlusal plane angulation. An upward positioning of the occlusal plane resulted in the projection of the hard palate over the apices of the maxillary teeth and elongation and enlargement of the maxillary molars. There was a corresponding reduction in size of the mandibular molars. A downward positioning of the occlusal plane resulted in the mesial-distal aspects of the teeth being narrowed and their relationships crowded. An overall linear magnification of 7 to 12 per cent was determined.

Christen[39] used copper wires, metal beads, lead foil, and stainless steel wire in his study. He cut the 0.050 gauge wire into 2.5 cm. sections and formed it into crosses. These markers were affixed to the maxilla and mandible to study the vertical and horizontal distortions. In the vertical plane, elongation of the pins averaged 14.5 per cent in the premolar region, 14 per cent in the molar region, and 10 per cent in the midramus area. A generalized shortening of the pins occurred along the horizontal plane with the premolar region showing a 4 per cent shortening, the molar a 5 per cent shortening, and a 20 per cent shortening in the midramus area. As the head position varied, both the vertical and horizontal distortions changed. When the chin was moved 1 cm. to the right of center, an enlargement of the right side occurred with a reduction in the left side. In this position a distortion in the vertical plane occurred equal to an increase of 19.5 per cent in the premolar area, 13.5 per cent in the molar area, and 11 per cent in the midramal region. Horizontal pin distortion remained unchanged except in the midramal region where it decreased from 20 per cent to 12 per cent.

To minimize distortion, the manufacturer's recommendations[40] for the operation of the 1971 model of Panorex involve having the patient sit very erect with the ala tragus line parallel with the floor. The patient's chin rests on the head positioner with the midsagittal plane of the head being centered. According to the manufacturer's specifications, the anterior teeth should be 2 15/32 inches from the film at the midmost portion of the cycle. As the patient positions his chin on the rest, the occlusal plane should point downward at an angle of five degrees. A cotton roll is placed between the teeth to prevent incisal overlap and the patient is asked to close the lips and place the tongue against the palate. With the patient remaining stationary, the tube head and cassette holder assembly rotate around the patient's head in a total rotational arc of 240 degrees. The chair automatically shifts 1 3/4 inches when the tube head reaches the midmost point of its excursion. The chair movement positions the two halves of the elliptical dental arch in an improved relationship to the source and the film, with a resultant reduction of distortion. The physical distance from the focal spot in the x-ray tube to the center of rotation is 12 inches and from the center of rotation to the film is 5 inches.

METHODS AND MATERIALS

Geometric Principles

A radiograph is a shadow picture of an object that has been placed in the path of an x-ray beam, between the tube anode and the film or between the source of radiation and the film. It follows that the appearance of an image thus recorded is materially influenced by the relative positions of the object and the film and by the direction of the beam.

X-rays obey the common laws of light in respect to image formation, and the geometry of the shadow formed may be explained in a simple manner in terms of light. The analogy between x-rays and light is not perfect as x-rays may not be refracted and focused with lenses and all objects are, at least to some degree, transparent to x-rays. Scatter also presents a greater problem in radiography than in optics. However, the same geometric laws of shadow formation are applied for light and penetrating radiation.

Mathematically the degree of enlargement may be calculated by use of the following equation:

$$\frac{S_o}{S_i} = \frac{D_o}{D_i}$$

where S_o is the size of the object, S_i is the size of the image, D_o is the distance from the source of radiation to the object, and D_i the distance from the source of radiation to the recording surface. Thus, stated simply, the diameter of the object is to the diameter of the image as the distance of the source from the object is to the distance of the source from the image.

Factors Affecting Radiographic Distortion

The basic principles of shadow formation must be given primary consideration to assure satisfactory sharpness in the radiographic image and essential freedom from distortion. A certain degree of distortion naturally will exist in every radiograph because certain parts of an anatomical object will always be farther from the film than others, the greatest magnification being evident in the images of those parts at the greatest distance from the film.

Distortion cannot be eliminated entirely, but by the use of an appropriate focal spot-film distance, it can be lessened to the point where it is not objectionable in the radiographic image.

The procedure which was followed in this study used five principles, which are listed below, to minimize the horizontal distortion encountered in the cuspid-premolar region which was the focus of this investigation.

The focal spot should be as small as other considerations will allow, for there is a definite relation between the size of the focal spot of the x-ray tube and the definition in the radiograph. A large focal spot, although capable of withstanding large loads, does not permit the delineation of as much detail as a fine focal spot. Long source-film distances will aid in showing detail when a large focal spot is employed in the radiographic system, but it is generally considered advantageous to use the smallest focal spot possible for the exposure required.

The distance between the source and the material examined should always be as great as is practical. At long distances, radiographic definition is improved and the image is more nearly the actual size of the object.

The film should be as close as possible to the object being radiographed.

The central ray should be as nearly perpendicular to the the film as possible to preserve spatial relations.

As far as the shape of the object will allow, the plane of maximum interest should be parallel to the plane of the film.

The trigonometric relationships which have been incorporated into the design of the Panorex unit were related to the proportional equation which relates object and image size, as noted earlier. Figure 1 illustrates a patient who has been positioned for a Panorex radiograph. The image size is represented by the distance FI, the source by S, the source-object distance by $SR + R_t\cos\phi$ (R being the center of rotation of the tube and film and R_t being the distance from the center of rotation to the object), and the size of the object by $R_t \sin \phi$. SF is the distance of the source to the film. The angle ϕ is created in the projection of the image of the teeth, T, during the excursion from T_1 to T_2. Therefore, substituting representative values:

$$\frac{S_o}{S_i} = \frac{D_o}{D_i}$$

$$S = R_t \sin \phi$$

$$S = FI$$

$$D = SR + R_t \cos \phi$$

$$D = SF$$

or

$$\frac{R_t \sin \phi}{FI} = \frac{SR + R_t \cos \phi}{SF}$$

In theory, one would like to have the object size equal the image size, that is, to eliminate magnification. This condition would be possible only under theoretical conditions. The distance from the source to the film and from the source to the center of rotation is constant and not alterable with this machine, which imposes a definite limitation if not a built-in error factor. The only relationship which is variable to the operator is $R_t \cos \phi$. Object and image size would be equal if the cos ϕ were one and this occurs only when the angle ϕ is 0 degrees or when the object and film coincide.

The question now arises as to how one might minimize and standardize the distortion encountered. The above equations demonstrate that the distortion may be decreased by bringing the subject as close to the film as is possible, neccessarily keeping him in the area of focus. A constant linear magnification can be obtained by keeping the object or objects in question at all times equidistant to the center of rotation or a constant object-film distance. In other words, when all objects lie on a plane which is parallel to the film and all points on this plane are equidistant from the source, uniform magnification results.

The manufacturer of the Panorex realized the distortion which would be encountered with the increased object-film distance. To alleviate some magnification, the linear velocity of the film is slightly greater than the linear velocity of the image being produced. This compensating factor and the other principles were applied in a test study to determine the degree to which distortion could be reduced.

Pilot Study

If the Panorex is to be used in predicting the dimensions of teeth, it becomes neccessary to make a film of an object, or series of objects, simulating a dental arch with a standardized or uniform distortion from one object to another in the series. To accomplish this step, the centers of rotation of the Panorex were located by dropping a plumb line from the axis of rotation to a grid which was attached to the chin rest. After the centers of rotation had been located, a compass was used to scribe circles of different radii, each being nearer the film but the tangent of which was at any instant of time parallel with the film or perpendicular with the central ray.

These circles of varying radii were inscribed into a plexiglass grid (Figure 2). Chrome steel wires (0.030) were vertically inset into the grid at five millimeter intervals on the circles. Panorex radiographs were exposed with the series of vertical wires located on circles of increasing radii from the center of rotation. The wires present on each circle represented a series of objects, all of which were equidistant from the center of rotation.

It was found that the series of vertical wires located on this arc had uniform magnification from one point to the next. In fact, if the objects were brought closer to the film on the circular arc, the center of which was the axis of rotation of the film and source, the degree of horizontal magnification could be decreased to one or two per cent.

The feasibility of adapting the radiographic technique to patients was subsequently determined with skulls of children.

Skulls with labial plates removed (Figure 3) were placed on a support attached to the Pancentric chin rest. The buccal surfaces of the primary first and second molars and primary maxillary cuspids were positioned as nearly as possible to the minimally distorted arc. Measurements of the erupted teeth in the same quadrant and the unerupted permanent first and second bicuspids and permanent cuspid demonstrated that similar results could be obtained (0 -5% error).

These preliminary exercises were of sufficient accuracy to warrant the design of a cephalostat for the child patient and further study of the radiographic technique. The need to limit patient movement and to guide the operator in patient positioning is obvious.

Several designs were attempted but the one which was employed (Figure 4) supported the patient's head by having him close his teeth on a plexiglass template which secured the teeth parallel to the floor. The cephalostat was attached to the Pancentric head positioner. The intraoral portion (Figure 5) was calibrated at five millimeter intervals by insetting metal into the plexiglass on a circular arc 65 millimeters from the axis of rotation. The calibrations were intended to be in the same vertical plane as the contact points of the primary molars and cuspids. The patient was positioned with the buccal cusps of the erupted teeth rotated against a stop mounted on the outer rim of the template.

Thus the experimental Panorex had variations as described below from the standard Panorex that was made according to the manufacturer's recommendations for patient positioning. After being positioned in the usual manner, the patient was asked to close his teeth on the plastic template. The head was rotated so that the buccal surfaces of the erupted primary molars and cuspids were against the outer rim of the template. The head was rotated approximately 28 degrees so that the quadrants which were filmed were not only closer to the film, but interproximal overlap was essentially eliminated (Figure 6).

Upon completion of the left quadrants, the patient was repositioned, the template reversed, and the right quadrants recorded on a different film. The left and right quadrants as viewed on the experimental Panorex films are shown in Figure 7.

The exposures were made at 10 milliamperage and a kilovoltage consistent with the head circumference. Kodak Blue Brand Panoramic dental x-ray film (5 x 11 1/2 in.) was used. All films were developed for three minutes, fixed for fifteen minutes, washed and dried. A similar procedure was followed for the Kodak occlusal and periapical films.

Techniques Employed for Plane Surface Radiographs

To determine the relative accuracy of the experimental procedure, the mesial-distal dimensions of teeth as measured from periapical, occlusal, standard Panorex film, and quadrant totals from Moyer's charts were compared statistically.

This was a cross sectional study which included a sample of fifty children, ages 6 to 11 years, equally divided according to race and sex. The children were selected randomly at the Indiana University School of Dentistry Pedodontic Clinic. All radiographs were taken and developed in the Indiana University School of Dentistry Department of Radiology. The mesial-distal dimensions of the cuspid and bicuspid teeth were measured from each of the radiographs. The mandibular incisors were measured intraorally to determine their actual dimensions. Measurements were made by two examiners and recorded on a data form (Figure 8). A Boley gauge with sharp calipers was used in the measuring of films and the erupted mandibular permanent incisor teeth. Measurements were recorded to the nearest tenth of a millimeter.

All periapical, occlusal, and Panorex radiographs, with the exception of the experimental film, were made with the technique recommended by the Indiana University Department of Radiology. Care was taken to follow the principles of recommended radiographic procedures as was conveniently possible, but there was no other attempt to standardize procedures. The following paragraphs summarize the techniques employed in obtaining these films.

The maxillary occlusal radiographs for cuspid and bicuspid teeth (Figure 9) were obtained by positioning the horizontal angle of the tube at fifteen degrees to the saggital plane, and the vertical angle at ninety degrees to the plane of occlusion. The central ray was directed through the infraorbital foramen. The mandibular occlusal radiograph (Figure 10) was obtained by placing the front side of the film packet facing the floor of the mouth. The head was tilted backward until the plane of occlusion was perpendicular to the plane of the floor. The horizontal and vertical angulation of the tube head was positioned so that the central ray was perpendicular to the plane of occlusion.

All periapical radiographs (Figure 11) of the maxillary cuspids and bicuspids were obtained by using a bisecting angle technique. The bisecting angle technique was used because of the anatomic problem of a low palatal vault, which is a frequent characteristic of the child patient, and its distorting consequence which would be exaggerated in the paralleling method and minimized with the bisecting angle technique. The object-film distance is also less in the bisecting angle technique. The mandibular cuspid and bicuspid radiographs were made with a paralleling technique, as the anatomical relationships associated with the mandible facilitated its use.

The standard Panorex films (Figure 12) were made with the method specified by the manufacturer. This operation involves having the patient sit very erect with the ala tragus plane parallel with the floor (Figure 13). The patient's chin rest on the Pancentric head positioner with the midsagital plane of the head being centered. The anterior teeth are 2 15/32 inches from the radiation source at the midmost portion of the cycle. As the patient positions the chin on the rest, the occlusal plane should point downward at an angle of five degrees. A cotton roll is place between the teeth to prevent incisal overlap and the patient is asked to close the lips and place the tongue against the palate.

RESULTS

Mean, variance, standard deviation, and degrees of significance were determined for the experimental and other radiographic groups. The statistical analysis used compared the dimensions obtained from the experimental Panorex with each radiographic method and Moyer's chart, determining an analysis of variance. The analysis of variance compares single criteria of classification with unequal group size. The Welch test was used to determine within but not between group difference if the probability for Bartlett's Chi Square was less than 0.5000. Tests between individual means were performed if the F-probability was less than 0.5000. The analysis also included the repeated t-test to compare the groups. Besides having used to compare the experimental group with each of the other methods, the t-test was used to compare all methods with each other.

The variables of race and sex, as well as the ability of two examiners to repeat the radiographic measurements independently, were similarly considered. All tables made from the computer output include insignificant digits for completeness. Measurements are significant to only one decimal point.

Table I (A-L) lists the mean mesial-distal dimensions of the unerupted cuspid and bicuspid teeth of fifty subjects as measured by four radiographic methods. The variances from the mean and the standard deviations are included.

Experimental Panorex

The mandibular teeth demonstrated the larger standard deviation from the mean in diameter with the experimental film. The mean mesial-distal diameter of the left cuspid was 7.8 mm. with a standard deviation of 0.9 mm., whereas the right cuspid mean was 7.9 mm. with a standard deviation of 0.9mm. The mean diameter of the left first bicuspid was 8.1 mm. with a standard deviation of 0.9 mm. The corresponding right first bicuspid had a mean diameter of 8.1 mm. with a standard deviation of 0.9 mm. The right and left second bicuspids had a mean diameter of 8.6 mm. The mean mesial-distal diameters of the maxillary left and right first bicuspids were 7.9 mm. and 7.8 mm. Their standard deviations were 0.7 mm. and 0.9 mm., respectively. The standard deviations of the second bicuspids were 0.8 mm. for the right and 0.7 mm. for the left. Their mean dimensions were 7.8 mm. and 8.0 mm., respectively.

The comparative values obtained from the standard Panorex, occlusal, and periapical films are also listed in Table I.

The computations of the mesial-distal diameters of the bicuspid and cuspids, as determined from the experimental Panorex and compared to the other radiographic methods, are also summarized in Table I (A-L). With the t-test, each of the radiographic methods could be compared to each of the other radiographic methods, and these results are included.

Measuring Differences

Table II (A-L) is a comparison of the degree in which two examiners, measuring the various radiographs independently, could duplicate results. Of the four radiographic techniques and the twelve teeth measured with each technique, a total of forty-eight variables, the greatest average mean difference between examiners occurred with the maxillary left second bicuspid which demonstrated a difference of 0.24 mm. Table II lists a single significantly different measurement between examiners. This difference occurred for the maxillary left second bicuspid as measured from the periapical radiograph. All other forty-seven of the forty-eight means demonstrated no significant difference from the mean. These results demonstrated acceptible reproducibility of measurement with the instrument employed.

Quadrant Totals Vs. Moyer's Totals

The estimate of tooth mass per quadrant (cuspid, first and second bicuspid) by Moyer's correlation chart provided a method for comparison which is independent and unrelated to radiographic interpretation. The Moyer's chart is possibly the most accurate method of obtaining the unerupted tooth mass. However, there was never a significant difference demonstrated between the sums of the mesial-distal dimension of the cuspid and bicuspids in a quadrant when obtained by an occlusal, periapical radiograph, or from Moyer's chart. Chart III (A-L) is a summary of the means, variances, and standard deviations, and the significance of the difference between the techniques used in obtaining the unerupted tooth mass in a given quadrant. The quadrant totals determined from the experimental Panorex were borderline or significantly different from Moyer's totals.

Variations Between Races

Variations between the Caucasian and Negro races were identified. Chart IV (A-L) summarizes the means, variances, and standard deviations of each of the cuspid and bicuspid teeth as observed for each of the two races and as identified by each of the four radiographic methods.

The mean mesial-distal dimension of the maxillary left first bicuspid was 7.7 mm. with a standard deviation of 0.6 mm. among the Caucasian group and 8.4 mm. with a standard deviation of 0.9 mm. among the Negro group. These values were obtained with the experimental method and demonstrated a significant difference.

Measurements of standard Panorex radiographs of the mesial-distal dimensions showed no significant difference between the two races observed. The mean dimension for the maxillary left first bicuspid for the caucasian group was 9.0 mm. with a standard deviation of 1.4 mm., and the mean for the Negro group was 9.1 mm. with a standard deviation of 1.1mm.

The dimension of the maxillary left first bicuspid obtained from the occlusal film had a mean value for the Caucasian group of 7.5 mm. with a standard deviation of 0.7 mm. The Negro group had a mean dimension of 8.0 mm. with a standard deviation of 0.9 mm. The dimensions obtained from the occlusal radiographs showed a significant difference between the two races.

For the Caucasian group, the mean value of the left first bicuspid, as determined from a periapical radiograph, was 7.6 mm., with a standard deviation of 0.6 mm. The Negro group had a mean value of 8.2 mm. and a standard deviation of 0.9 mm., which was significantly different from the Caucasians. The differences of the other cuspid and bicuspid teeth between the two races are summarized in Table IV.

Variations Between Sexes

To demonstrate further the variability with the study group, differences in the mesial-distal dimensions between male and female populations were determined. Table V (A-H) summarizes the means, standard deviations, and degrees of significance of the dimensions of the unerupted cuspids and bicuspids as determined by each radiographic method. The sample included twenty-three males and twenty-seven females.

With the experimental panoramic method of obtaining the mesial-distal dimensions, males demonstrated greater mean dimensions for each of the teeth studied. The maxillary right second bicuspid of the male group had a mean dimension of 8.1 mm. with a standard deviation of 0.9 mm. as compared to the female group which had a mean dimension of 7.6 mm. with a standard deviation of 0.7 mm. These values differed significantly at the .05 critical level but not at the .01 critical level. A very similar pattern is demonstrated by the other unerupted teeth, as seen in Table V.

With the standard Panorex method, dimensions for the male had a mean of 9.6 mm. with a standard deviation of 1.7 mm. for the maxillary right second bicuspid, whereas the female group had a mean of 9.1 mm. with a standard deviation of 1.8 mm. These values were not significantly different.

The same bicuspid had a mean dimension of 7.5 mm. with a standard deviation of 1.0 for the males and 7.3 mm. with a standard deviation of 0.8 mm. for the females when measured with the occlusal radiograph. Again, these were not significantly different.

Dimensions recorded from periapical radiographs also demonstrated no real difference between the sexes for the maxillary right second bicuspid. The mean value for the males was 7.6 mm.

with a standard deviation of 0.9 mm., for the females it was 7.4 mm., with a standard deviation of 0.7 mm.

The results of the other cuspids and bicuspids are listed in Table V.

TABLES

TABLE I

TABLE I - A

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE ERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS

MAXILLARY RIGHT SECOND BICUSPID

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	7.79800	0.66224	0.81378	50
2. Panorex	9.33800	1.05261	1.02597	50
3. Occlusal	7.38000	0.25061	0.50061	50
4. Periapical	7.51400	0.25880	0.50870	50

Individual comparisons of methods -Repeated t-tests

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	.01
(1) - (2)	1.5400	20.485	93	8.316	1.99*	2.64**
(1) - (3)	0.4180	5.562	81	3.094	1.99*	2.64**
(1) - (4)	0.2840	3.779	82	2.093	1.99*	2.64
(2) - (3)	1.9580	26.058	71	12.128	2.00*	2.65**
(2) - (4)	1.8240	24.274	72	11.263	2.00*	2.65**
(3) - (4)	0.1340	1.783	98	1.328	1.99	2.63

TABLE I - B

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE ERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS

MAXILLARY RIGHT FIRST BICUSPID

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	7.78200	0.72844	0.85349	50
2. Panorex	8.97800	0.79032	0.88900	50
3. Occlusal	7.50200	0.32469	0.56982	50
4. Periapical	7.59200	0.24157	0.49150	50

Individual comparisons of methods -Repeated t-tests

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	.01
(1) - (2)	1.1960	15.753	98	6.862	1.99*	2.63**
(1) - (3)	0.2800	3.688	85	1.929	1.99	2.64
(1) - (4)	0.1900	2.502	79	1.364	1.99	2.65
(2) - (3)	1.4760	19.441	83	9.884	1.99*	2.64**
(2) - (4)	1.3860	18.430	76	9.648	2.00*	2.65**
(3) - (4)	0.0900	1.185	96	0.846	1.99	2.63

TABLE I - C

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE ERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS

MAXILLARY RIGHT CUSPID

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	8.53800	0.738322	0.85926	50
2. Panorex	8.24400	0.483331	0.69522	50
3. Occlusal	8.43600	0.428882	0.65490	50
4. Periapical	8.37200	0.319200	0.56498	50

Individual comparisons of methods -Repeated t-tests

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	.01
(1) - (2)						
(1) - (3)						
(1) - (4)	All groups homogenous					
(2) - (3)						
(2) - (4)						
(3) - (4)						

TABLE I - D

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE ERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS

MAXILLARY LEFT CUSPID

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	8.46000	0.76612	0.87528	50
2. Panorex	8.32999	0.46255	0.68011	50
3. Occlusal	8.38200	0.38967	0.62424	50
4. Periapical	8.33199	0.28671	0.53545	50

Individual comparisons of methods -Repeated t-tests

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	.01
(1) - (2)						
(1) - (3)						
(1) - (4)	All groups homogenous					
(2) - (3)						
(2) - (4)						
(3) - (4)						

TABLE I - E

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE ERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS

MAXILLARY LEFT FIRST BICUSPID

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	7.89600	0.54570	0.73871	50
2. Panorex	9.03199	0.52957	0.72771	50
3. Occlusal	7.59400	0.34425	0.58673	50
4. Periapical	7.73800	0.35057	0.59209	50

Individual comparisons of methods -Repeated t-tests

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	.01
(1) - (2)	1.1360	17.575		8.539	1.96*	2.57**
(1) - (3)	0.3020	3.902		2.270	1.96*	2.57**
(1) - (4)	0.1580	3.902		1.188	1.96	2.57
(2) - (3)	1.4380	18.583		10.809	1.96*	2.57**
(2) - (4)	1.2940	16.722		9.726	1.96*	2.57**
(3) - (4)	0.1440	1.860		1.082	1.96	2.57

TABLE I - F

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE ERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS

<u>MAXILLARY LEFT SECOND BICUSPID</u>

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	7.94000	0.45224	0.67249	50
2. Panorex	9.27000	0.67316	0.82047	50
3. Occlusal	7.44000	0.26735	0.51706	50
4. Periapical	7.59000	0.26133	0.51120	50

Individual comparisons of methods -Repeated t-tests

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	CRITICAL VALUES .01
(1) - (2)	1.3300	17.523	94	8.865	1.99*	2.63**
(1) - (3)	0.5000	5.820	92	4.168	1.99*	2.64**
(1) - (4)	0.3500	4.611	91	2.930	1.99*	2.64**
(2) - (3)	1.8300	24.110	83	13.343	1.99*	2.64**
(2) - (4)	1.6800	22.134	82	12.289	1.99*	2.64**
(3) - (4)	0.1500	1.976	98	1.459	1.99	2.63

TABLE I - G

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE ERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS

<u>MANDIBULAR LEFT SECOND BICUSPID</u>

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	8.54599	0.76376	0.87393	50
2. Panorex	9.49799	0.70918	0.84213	50
3. Occlusal	8.17600	0.65574	0.80978	50
4. Periapical	8.03399	0.33290	0.57698	50

Individual comparisons of methods -Repeated t-tests

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	.01
(1) - (2)	0.9520	11.849	98	5.547	1.99*	2.63**
(1) - (3)	0.3700	4.605	97	2.196	1.99*	2.63
(1) - (4)	0.5120	6.372	85	3.457	1.99*	2.64**
(2) - (3)	1.3220	16.455	98	8.001	1.99*	2.63**
(2) - (4)	1.4640	18.222	87	10.141	1.99*	2.64**
(3) - (4)	0.1420	1.767	89	1.010	1.99	2.64

TABLE I - H

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE ERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS

MANDIBULAR LEFT FIRST BICUSPID

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	8.06600	0.77453	0.88008	50
2. Panorex	8.49600	0.64407	0.80254	50
3. Occlusal	7.59400	0.41323	0.64283	50
4. Periapical	7.76600	0.59984	0.77450	50

Individual comparisons of methods -Repeated t-tests

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	.01
(1) - (2)	0.4300	5.536		2.758	1.96*	2.57**
(1) - (3)	0.4720	6.077		3.027	1.96*	2.57**
(1) - (4)	0.3000	3.862		1.924	1.96	2.57
(2) - (3)	0.9020	11.614		5.785	1.96*	2.57**
(2) - (4)	0.7300	9.399		4.681	1.96*	2.57**
(3) - (4)	0.1720	2.214		1.103	1.96	2.57

TABLE I - I

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE ERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS

MANDIBULAR LEFT CUSPID

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	7.84199	0.88780	0.94223	50
2. Panorex	7.94200	0.65718	0.81067	50
3. Occlusal	7.63400	0.55209	0.74302	50
4. Periapical	7.37400	0.32237	0.56778	50

Individual comparisons of methods -Repeated t-tests

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	.01
(1) - (2)	0.1000	1.356	96	0.569	1.99	2.63
(1) - (3)	0.2080	2.820	93	1.226	1.99	2.64
(1) - (4)	0.4680	6.346	80	3.008	1.99*	2.64**
(2) - (3)	0.3080	4.176	97	1.981	1.99	2.64
(2) - (4)	0.5680	7.702	88	4.058	1.99*	2.64**
(3) - (4)	0.2600	3.525	92	1.966	1.99	2.64

TABLE I - J

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE ERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS

<u>MANDIBULAR RIGHT CUSPID</u>

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	7.90400	0.82815	0.91003	50
2. Panorex	7.94000	0.75306	0.86779	50
3. Occlusal	7.78800	0.71332	0.84458	50
4. Periapical	7.48000	0.42531	0.65215	50

Individual comparisons of methods -Repeated t-tests

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	.01
(1) - (2)	0.0360	0.481		0.218	1.96	2.57
(1) - (3)	0.1160	1.550		0.703	1.96	2.57
(1) - (4)	0.4240	5.668		2.571	1.96*	2.57**
(2) - (3)	0.1520	2.032		0.922	1.96	2.57
(2) - (4)	0.4600	6.149		2.789	1.96*	2.57**
(3) - (4)	0.3080	4.117		1.868	1.96	2.57

TABLE I - K

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE ERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS

MANDIBULAR RIGHT FIRST BICUSPID

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	8.13399	0.72596	0.85203	50
2. Panorex	8.56600	0.60311	0.77660	50
3. Occlusal	7.66400	0.49745	0.70530	50
4. Periapical	7.84800	0.40214	0.63414	50

Individual comparisons of methods -Repeated t-tests

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	.01
(1) - (2)	0.4320	5.504		2.894	1.96*	2.57**
(1) - (3)	0.4700	5.988		3.148	1.96*	2.57**
(1) - (4)	0.2860	3.644		1.916	1.96	2.57
(2) - (3)	0.9020	11.493		6.042	1.96*	2.57**
(2) - (4)	0.7180	9.148		4.810	1.96*	2.57**
(3) - (4)	0.1840	2.344		1.233	1.96	2.57

TABLE I - L

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE ERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS

MANDIBULAR RIGHT SECOND BICUSPID

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	8.56400	0.66194	0.81359	50
2. Panorex	9.60000	0.83265	0.91250	50
3. Occlusal	8.07400	0.55298	0.74363	50
4. Periapical	8.02000	0.36531	0.60441	50

Individual comparisons of methods -Repeated t-tests

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	.01
(1) - (2)	1.0360	12.917	97	5.992	1.99*	2.63**
(1) - (3)	0.4900	6.109	97	3.143	1.99*	2.63**
(1) - (4)	0.5440	6.783	90	3.795	1.99*	2.63**
(2) - (3)	1.5260	19.027	94	9.167	1.99*	2.63**
(2) - (4)	1.5800	19.700	85	10.208	1.99*	2.64**
(3) - (4)	0.0540	0.673	94	0.398	1.99	2.63

TABLE II

TABLE II - A

SUMMARY OF THE MEANS, VARIANCES, SIGNIFICANCE OF DIFFERENCE, AND THE ANALYSIS OF VARIANCE OF THE UNERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS AND DETERMINED BY TWO EXAMINERS

MAXILLARY RIGHT SECOND BICUSPID

EXAMINER	METHOD	MEAN	VARIANCE	STD. DEVIATION	SAMPLE
A	Exp. Panorex	7.79800	0.66224	0.81378	50
B		7.80000	0.79796	0.89326	
A	Panorex	9.33800	3.08224	1.75563	50
B		9.15600	2.67422	1.63530	
A	Occlusal	7.38000	0.84053	0.91680	50
B		7.26400	1.09112	1.04456	
A	Periapical	7.51400	0.74454	0.86287	50
B		7.39800	0.96286	0.98125	

Analysis of variance

EXAMINERS	METHOD	DF.	SUM OF SQUARES	MEAN SQUARE	F
A vs. B	Exp. Panorex	99	71.5486	0.7301	0.0003
A vs. B	Panorex	99	95.2676	0.9637	0.8595
A vs. B	Occlusal	99	28.0306	0.2826	1.1907
A vs. B	Periapical	99	25.6653	0.2585	1.3021

TABLE II - B

SUMMARY OF THE MEANS, VARIANCES, SIGNIFICANCE OF DIFFERENCE, AND THE ANALYSIS OF VARIANCE OF THE UNERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS AND DETERMINED BY TWO EXAMINERS

MAXILLARY RIGHT FIRST BICUSPID

EXAMINER	METHOD	MEAN	VARIANCE	STD. DEVIATION	SAMPLE
A	Exp. Panorex	7.78200	0.72844	0.85349	50
B		7.80600	0.72262	0.85007	
A	Panorex	8.97799	2.18805	1.47920	50
B		8.80800	1.74711	1.32178	
A	Occlusal	7.50200	0.80844	0.89914	50
B		7.31600	0.96762	0.98367	
A	Periapical	7.51999	0.76528	0.87480	50
B		7.46000	0.84478	0.91911	

Analysis of variance

EXAMINERS	METHOD	DF	SUM OF SQUARES	MEAN SQUARE	F
A vs. B	Exp. Panorex	99	71.1151	0.7255	0.0200
A vs. B	Panorex	99	79.3037	0.8018	0.9012
A vs. B	Occlusal	99	34.4008	0.3422	2.5277
A vs. B	Periapical	99	28.3714	0.2851	1.5286

TABLE II - C

SUMMARY OF THE MEANS, VARIANCES, SIGNIFICANCE OF DIFFERENCE, AND THE ANALYSIS OF VARIANCE OF THE UNERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS AND DETERMINED BY TWO EXAMINERS

MAXILLARY RIGHT CUSPID

EXAMINER	METHOD	MEAN	VARIANCE	STD. DEVIATION	SAMPLE
A	Exp. Panorex	8.53800	0.73832	0.85926	50
B		8.57999	0.73306	0.85619	
A	Panorex	8.24400	0.82652	0.90913	50
B		8.14399	0.92704	0.96283	
A	Occlusal	8.43600	0.74894	0.86441	50
B		8.32600	0.79889	0.89381	
A	Periapical	8.37200	0.76644	0.87547	50
B		8.30199	0.81192	0.90107	

Analysis of variance

EXAMINERS	METHOD	DF	SUM OF SQUARES	MEAN SQUARE	F
A vs. B	Exp. Panorex	99	72.1404	0.7357	0.0601
A vs. B	Panorex	99	52.8351	0.5366	0.4663
A vs. B	Occlusal	99	44.7325	0.4534	0.6675
A vs. B	Periapical	99	33.8517	0.3442	0.3563

TABLE II - D

SUMMARY OF THE MEANS, VARIANCES, SIGNIFICANCE OF DIFFERENCE, AND THE ANALYSIS OF VARIANCE OF THE UNERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS AND DETERMINED BY TWO EXAMINERS

MAXILLARY LEFT CUSPID

EXAMINER	METHOD	MEAN	VARIANCE	STD. DEVIATION	SAMPLE
A	Exp. Panorex	8.46000	0.76612	0.87528	50
B		8.53119	0.79732	0.89293	
A	Panorex	8.32999	0.78337	0.88508	50
B		8.23000	0.89039	0.94360	
A	Occlusal	8.38200	0.77233	0.87882	50
B		8.28000	0.86212	0.92850	
A	Periapical	8.33199	0.78284	0.88478	50
B		8.19999	0.90979	0.95383	

Analysis of variance

EXAMINERS	METHOD	DF	SUM OF SQUARES	MEAN SQUARE	F
A vs. B	Exp. Panorex	99	76.7366	0.7817	0.1658
A vs. B	Panorex	99	46.8587	0.4765	0.5259
A vs. B	Occlusal	99	40.3925	0.4095	0.6355
A vs. B	Periapical	99	29.5032	0.2966	1.4686

TABLE II - E

SUMMARY OF THE MEANS, VARIANCES, SIGNIFICANCE OF DIFFERENCE, AND THE ANALYSIS OF VARIANCE OF THE UNERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS AND DETERMINED BY TWO EXAMINERS

MAXILLARY LEFT FIRST BICUSPID

EXAMINER	METHOD	MEAN	VARIANCE	STD. DEVIATION	SAMPLE
A	Exp. Panorex	7.89600	0.54570	0.73871	50
B		7.87200	0.54981	0.74149	
A	Panorex	9.03199	1.86253	1.36475	50
B		8.93999	1.71371	1.30909	
A	Occlusal	7.59400	0.63876	0.79923	50
B		7.48999	0.69871	0.83589	
A	Periapical	7.73800	0.57117	0.75576	50
B		7.58400	0.63445	0.79652	

Analysis of variance

EXAMINERS	METHOD	DF	SUM OF SQUARES	MEAN SQUARE	F
A vs. B	Exp. Panorex	99	53.6929	0.5477	0.0265
A vs. B	Panorex	99	54.3589	0.5525	0.3831
A vs. B	Occlusal	99	39.0625	0.3958	0.6837
A vs. B	Periapical	99	35.1569	0.3527	1.6814

TABLE II - F

SUMMARY OF THE MEANS, VARIANCES, SIGNIFICANCE OF DIFFERENCE, AND THE ANALYSIS OF VARIANCE OF THE UNERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS AND DETERMINED BY TWO EXAMINERS

MAXILLARY LEFT SECOND BICUSPID

EXAMINER	METHOD	MEAN	VARIANCE	STD. DEVIATION	SAMPLE
A	Exp. Panorex	7.94000	0.45224	0.67249	50
B		7.98400	0.51851	0.72008	
A	Panorex	9.27000	2.25724	1.50241	50
B		9.21400	2.06229	1.43607	
A	Occlusal	7.44000	0.70735	0.84104	50
B		7.29200	1.00715	1.00357	
A	Periapical	7.59000	0.57724	0.75977	50
B		7.35000	0.92867	0.96368	

Analysis of variance

EXAMINERS	METHOD	DF	SUM OF SQUARES	MEAN SQUARE	F
A vs. B	Exp. Panorex	99	47.6143	0.4854	0.1000
A vs. B	Panorex	99	84.3817	0.8602	0.0911
A vs. B	Occlusal	99	29.6230	0.2967	1.8457
A vs. B	Periapical	99	26.2889	0.2536	5.6796**

TABLE II - G

SUMMARY OF THE MEANS, VARIANCES, SIGNIFICANCE OF DIFFERENCE, AND THE ANALYSIS OF VARIANCE OF THE UNERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS AND DETERMINED BY TWO EXAMINERS

MANDIBULAR LEFT SECOND BICUSPID

EXAMINER	METHOD	MEAN	VARIANCE	STD. DEVIATION	SAMPLE
A	Exp. Panorex	8.54599	0.76376	0.87393	50
B		8.52399	0.84104	0.91708	
A	Panorex	9.49799	1.68856	1.29944	50
B		9.42399	1.66758	1.29134	
A	Occlusal	8.17600	0.90345	0.90505	50
B		8.15000	0.98378	0.99185	
A	Periapical	8.03399	1.03125	1.01551	50
B		7.97800	1.14524	1.07011	

Analysis of variance

EXAMINERS	METHOD	DF	SUM OF SQUARES	MEAN SQUARE	F
A vs. B	Exp. Panorex	99	78.6461	0.8024	0.0152
A vs. B	Panorex	99	67.0762	0.6831	0.2007
A vs. B	Occlusal	99	60.5319	0.6175	0.0275
A vs. B	Periapical	99	35.2354	0.3587	0.2190

TABLE II - H

SUMMARY OF THE MEANS, VARIANCES, SIGNIFICANCE OF DIFFERENCE, AND THE ANALYSIS OF VARIANCE OF THE UNERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS AND DETERMINED BY TWO EXAMINERS

MANDIBULAR LEFT FIRST BICUSPID

EXAMINER	METHOD	MEAN	VARIANCE	STD. DEVIATION	SAMPLE
A	Exp. Panorex	8.06600	0.77453	0.88008	50
B		8.09400	0.82915	0.91058	
A	Panorex	8.49599	0.96321	0.98143	50
B		8.40599	0.92848	0.96358	
A	Occlusal	7.59400	1.00187	1.03449	50
B		7.60800	1.07016	1.03449	
A	Periapical	7.76000	0.86637	0.93079	50
B		7.67999	1.00404	1.00202	

Analysis of variance

EXAMINERS	METHOD	DF	SUM OF SQUARES	MEAN SQUARE	F
A vs. B	Exp. Panorex	99	78.5984	0.8018	0.0246
A vs. B	Panorex	99	66.9888	0.6815	0.2973
A vs. B	Occlusal	99	33.9486	0.3463	0.0146
A vs. B	Periapical	99	58.6558	0.5966	0.3101

TABLE II - I

SUMMARY OF THE MEANS, VARIANCES, SIGNIFICANCE OF DIFFERENCE, AND THE ANALYSIS OF VARIANCE OF THE UNERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS AND DETERMINED BY TWO EXAMINERS

MANDIBULAR LEFT CUSPID

EXAMINER	METHOD	MEAN	VARIANCE	STD. DEVIATION	SAMPLE
A	Exp. Panorex	7.84199	0.88780	0.94223	50
B		7.73400	0.82392	0.90770	
A	Panorex	7.94200	0.89799	0.94763	50
B		7.82799	0.83294	0.91265	
A	Occlusal	7.63399	0.93194	0.96537	50
B		7.67000	0.82810	0.91000	
A	Periapical	7.37400	1.11129	1.05418	50
B		7.29200	1.02327	1.01157	

Analysis of variance

EXAMINERS	METHOD	DF	SUM OF SQUARES	MEAN SQUARE	F
A vs. B	Exp. Panorex	99	84.1643	0.8558	0.3408
A vs. B	Panorex	99	71.2263	0.7235	0.4492
A vs. B	Occlusal	99	56.6484	0.5777	0.0563
A vs. B	Periapical	99	36.4000	0.3697	0.4548

TABLE II - J

SUMMARY OF THE MEANS, VARIANCES, SIGNIFICANCE OF DIFFERENCE, AND THE ANALYSIS OF VARIANCE OF THE UNERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS AND DETERMINED BY TWO EXAMINERS

MANDIBULAR RIGHT CUSPID

EXAMINER	METHOD	MEAN	VARIANCE	STD. DEVIATION	SAMPLE
A	Exp. Panorex	7.90400	0.82815	0.91003	50
B		7.79400	0.88874	0.94273	
A	Panorex	7.94000	0.82947	0.91075	50
B		7.87600	0.89560	0.94636	
A	Occlusal	7.78800	0.84188	0.91754	50
B		7.57000	0.93994	0.96950	
A	Periapical	7.48000	1.01159	1.00578	50
B		7.32799	1.11033	1.05372	

Analysis of variance

EXAMINERS	METHOD	DF	SUM OF SQUARES	MEAN SQUARE	F
A vs. B	Exp. Panorex	99	84.4285	0.8584	0.3524
A vs. B	Panorex	99	79.1321	0.8064	0.1272
A vs. B	Occlusal	99	67.4248	0.6759	1.7580
A vs. B	Periapical	99	46.3774	0.4673	1.2361

TABLE II - K

SUMMARY OF THE MEANS, VARIANCES, SIGNIFICANCE OF DIFFERENCE, AND THE ANALYSIS OF VARIANCE OF THE UNERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS AND DETERMINED BY TWO EXAMINERS

MANDIBULAR RIGHT FIRST BICUSPID

EXAMINER	METHOD	MEAN	VARIANCE	STD. DEVIATION	SAMPLE
A	Exp. Panorex	8.13399	0.72596	0.85203	50
B		8.05600	0.76415	0.87415	
A	Panorex	8.56600	0.91640	0.95729	50
B		8.30399	0.82691	0.90934	
A	Occlusal	7.66400	0.95137	0.97538	50
B		7.61000	0.96712	0.98342	
A	Periapical	7.84800	0.80943	0.89968	50
B		7.71400	0.88350	0.93995	

Analysis of variance

EXAMINERS	METHOD	DF	SUM OF SQUARES	MEAN SQUARE	F
A vs. B	Exp. Panorex	99	73.1661	0.7450	0.2043
A vs. B	Panorex	99	112.0661	1.1260	1.5242
A vs. B	Occlusal	99	45.9119	0.4677	0.1561
A vs. B	Periapical	99	39.3925	0.3974	1.1300

TABLE II - L

SUMMARY OF THE MEANS, VARIANCES, SIGNIFICANCE OF DIFFERENCE, AND THE ANALYSIS OF VARIANCE OF THE UNERUPTED CUSPIDS AND BICUSPIDS AS DETERMINED RADIOGRAPHICALLY BY FOUR METHODS AND DETERMINED BY TWO EXAMINERS

MANDIBULAR RIGHT SECOND BICUSPID

EXAMINER	METHOD	MEAN	VARIANCE	STD. DEVIATION	SAMPLE
A	Exp. Panorex	8.56399	0.66194	0.81360	50
B		8.49799	0.76142	0.87260	
A	Panorex	9.59999	1.75714	1.32558	50
B		9.53800	1.86509	1.36569	
A	Occlusal	8.07399	0.90694	0.95234	50
B		8.10799	0.91662	0.95740	
A	Periapical	8.02000	0.96392	0.98179	50
B		7.92600	1.09529	1.04656	

Analysis of variance

EXAMINERS	METHOD	DF	SUM OF SQUARES	MEAN SQUARE	F
A vs. B	Exp. Panorex	99	69.8527	0.7117	0.1533
A vs. B	Panorex	99	75.1719	0.7661	0.1256
A vs. B	Occlusal	99	64.2807	0.6556	0.0444
A vs. B	Periapical	99	37.8158	0.3836	0.5760

TABLE III

TABLE III - A

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE UNERUPTED TOOTH MASS OF EACH QUADRANT AS DETERMINED RADIOGRAPHICALLY AND WITH MOYER'S CHART

MAXILLARY RIGHT QUADRANT

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	24.11800	5.11375	2.26136	50
2. Panorex	26.56000	4.72775	2.17434	50
3. Occlusals	23.31800	2.41211	1.55309	50
4. Periapicals	23.47800	1.73154	1.31588	50
5. Moyer's	23.37250	0.79076	0.88924	40

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	.01
(1) - (2)	2.4420	10.448	98	5.504	1.99*	2.63**
(1) - (3)	0.8000	3.422	87	2.062	1.99*	2.64
(1) - (4)	0.6400	2.738	79	1.730	1.99	2.65
(1) - (5)	0.7455	3.189	67	2.134	2.00*	2.65
(2) - (3)	3.24200	13.871	89	8.579	1.99*	2.64**
(2) - (4)	3.0820	13.186	81	8.575	1.99*	2.64**
(2) - (5)	3.1875	13.637	68	9.427	2.00*	2.65**
(3) - (4)	0.1600	0.684	95	0.556	1.99	2.63
(3) - (5)	0.0545	0.233	80	0.209	1.99	2.64
(4) - (5)	0.1055	0.450	86	0.452	1.99	2.64

TABLE III - B

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE UNERUPTED TOOTH MASS OF EACH QUADRANT AS DETERMINED RADIOGRAPHICALLY AND WITH MOYER'S CHART

MAXILLARY LEFT QUADRANT

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	24.29600	3.81794	1.95395	50
2. Panorex	26.63200	3.51446	1.87469	50
3. Occlusals	23.41600	2.12014	1.45607	50
4. Periapicals	23.66000	1.75346	1.32418	50
5. Moyer's	23.37250	0.79076	0.88924	40

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	.01
(1) - (2)	2.3360	9.994	98	6.100	1.99*	2.63**
(1) - (3)	0.8800	3.765	91	2.554	1.99*	2.64
(1) - (4)	0.6360	2.721	86	1.905	1.99	2.64
(1) - (5)	0.9235	3.951	72	2.979	2.00*	2.65**
(2) - (3)	3.2160	13.759	92	9.580	1.99*	2.64**
(2) - (4)	2.9720	12.715	88	9.156	1.99*	2.64**
(2) - (5)	3.2595	13.945	73	10.861	2.00*	2.65**
(3) - (4)	0.2440	1.043	97	0.877	1.99	2.63
(3) - (5)	0.0435	0.186	83	0.174	1.99	2.64
(4) - (5)	0.2875	1.230	86	1.228	1.99	2.64

TABLE III - C

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE UNERUPTED TOOTH MASS OF EACH QUADRANT AS DETERMINED RADIOGRAPHICALLY AND WITH MOYER'S CHART

MANDIBULAR LEFT QUADRANT

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	24.45400	5.52988	2.35157	50
2. Panorex	25.93600	3.97949	1.99486	50
3. Occlusals	23.40400	2.79059	1.67050	50
4. Periapicals	23.17400	2.44277	1.56293	50
5. Moyer's	23.04750	0.88101	0.93862	40

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	.01
(1) - (2)	1.4820	6.430	95	3.398	1.99*	2.63**
(1) - (3)	1.0500	4.555	88	2.574	1.99*	2.64
(1) - (4)	1.2800	5.553	85	3.205	1.99*	2.64**
(1) - (5)	1.4065	6.102	67	3.862	2.00*	2.65**
(2) - (3)	2.5320	10.986	95	6.881	1.99*	2.63**
(2) - (4)	2.7620	11.983	93	7.707	1.99*	2.64**
(2) - (5)	2.8885	12.532	73	9.061	2.00*	2.65**
(3) - (4)	0.2300	0.997	98	0.711	1.99	2.63
(3) - (5)	0.3565	1.546	80	1.278	1.99	2.64
(4) - (5)	0.1265	0.548	82	0.475	1.99	2.64

TABLE III - D

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE UNERUPTED TOOTH MASS OF EACH QUADRANT AS DETERMINED RADIOGRAPHICALLY AND WITH MOYER'S CHART

MANDIBULAR RIGHT QUADRANT

TECHNIQUE	MEAN	VARIANCE	STD. DEV.	SAMPLE
1. Exp. Panorex	24.60200	5.43938	2.33224	50
2. Panorex	26.10600	4.94996	2.22485	50
3. Occlusals	23.52600	3.54318	1.88233	50
4. Periapicals	23.34800	2.52418	1.58877	50
5. Moyer's	23.04750	0.88102	0.93862	40

MEAN PAIRS	DIFFERENCE FROM MEAN	% DIFFERENCE FROM MEAN	DF	T'	CRITICAL VALUES .05	CRITICAL VALUES .01
(1) - (2)	1.5040	6.525	98	3.299	1.99*	2.63**
(1) - (3)	1.0760	4.668	94	2.539	1.99*	2.63
(1) - (4)	1.2540	5.440	86	3.142	1.99*	2.64**
(1) - (5)	1.5545	6.744	67	4.298	2.00*	2.65**
(2) - (3)	2.5800	11.194	95	6.260	1.99*	2.63**
(2) - (4)	2.7580	11.966	89	7.133	1.99*	2.64**
(2) - (5)	3.0585	13.270	69	8.792	2.00*	2.65**
(3) - (4)	0.1780	0.772	95	0.511	1.99	2.63
(3) - (5)	0.4785	2.076	75	1.570	2.00	2.65
(4) - (5)	0.3005	1.303	82	1.116	1.99	2.64

TABLE IV

TABLE IV - A

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE UNERUPTED TOOTH MASS BETWEEN THE CAUCASIAN AND NEGRO RACES AS DETERMINED BY FOUR RADIOGRAPHIC METHODS

EXPERIMENTAL PANOREX METHOD

RACE	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
maxillary right second bicuspid								
Caucasian	7.66579	0.65204	0.80750	0.5509	4.4757	2.116	2.01*	2.68
Negro	8.21667	0.50515	0.71074					
maxillary right first bicuspid								
Caucasian	7.56842	0.62438	0.69865	0.8899	12.177	3.490	2.01*	2.68**
Negro	8.45833	0.48810	0.69865					
maxillary right cuspid								
Caucasian	8.38684	0.62063	0.78780	0.6298	5.3334	2.309	2.01*	2.68
Negro	9.01667	0.87242	0.93404					
maxillary left cuspid								
Caucasian	8.25526	0.70740	0.84107	0.8531	10.309	3.211	2.01*	2.68**
Negro	9.10833	0.42992	0.65569					
maxillary left first bicuspid								
Caucasian	7.73684	0.39644	0.62964	0.6632	8.4704	2.910	2.10*	2.68**
Negro	8.40000	0.73273	0.85599					
maxillary left second bicuspid								
Caucasian	7.79737	0.34405	0.58655	0.5943	8.1641	2.857	2.10*	2.68**
Negro	8.39167	0.56447	0.75131					

TABLE IV - B

EXPERIMENTAL PANOREX METHOD

RACE	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
mandibular left second bicuspid								
Caucasian	8.41842	0.67776	0.82326		3.5500			
Negro	8.95000	0.88818	0.94243					
mandibular left first bicuspid								
Caucasian	7.81052	0.62313	0.78939	1.0645	17.9064	4.238	2.01*	2.68**
Negro	8.87500	0.41477	0.64402					
mandibular left cuspid								
Caucasian	7.59211	0.64885	0.80552	1.0412	14.1192	3.758	2.01*	2.68**
Negro	8.63333	0.87333	0.93452					
mandibular right cuspid								
Caucasian	7.70000	0.61838	0.78637	0.8500	9.3053	3.050	2.01*	2.68**
Negro	8.55000	1.01000	1.00499					
mandibular right first bicuspid								
Caucasian	7.92631	0.51496	0.71761	0.8654	11.4052	3.377	2.01*	2.68**
Negro	8.79167	0.88083	0					
mandibular right second bicuspid								
Caucasian	8.43947	0.56299	0.75033		3.9313			
Negro	8.95833	0.83174	0.91200					

TABLE IV - C

STANDARD PANOREX

RACE	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
maxillary right second bicuspid								
Caucasian	9.25263	3.23817	1.79949		1.0985			
Negro	9.60833	2.61795	1.61801					
maxillary right first bicuspid								
Caucasian	8.89211	2.42388	1.55688		1.4931			
Negro	9.25000	1.7181	1.08251					
maxillary right cuspid								
Caucasian	8.19473	0.65853	0.81150		0.7918			
Negro	8.40000	1.28727	1.13458					
maxillary left cuspid								
Caucasian	8.33158	0.71339	0.84462		0.0009			
Negro	8.32500	1.09932	1.04848					
maxillary left first bicuspid								
Caucasian	9.02105	2.09021	1.44576		0.0351			
Negro	9.06666	1.21757	1.10344					
maxillary left second bicuspid								
Caucasian	9.27105	2.57449	1.60452		0.004			
Negro	9.26667	1.39970	1.18309					

TABLE IV - D

STANDARD PANOREX

RACE	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
mandibular left second bicuspid								
Caucasian	9.41579	1.69939	1.30361		1.5252			
Negro	9.75833	1.60099	1.26530					
mandibular left first bicuspid								
Caucasian	8.36052	0.93380	0.96633	0.5645	4.8682	2.206	2.01*	2.68
Negro	8.92500	0.41750	0.64614					
mandibular left cuspid								
Caucasian	7.78684	0.68780	0.82934	0.6465	6.4448	2.539	2.01*	2.68
Negro	8.43333	0.91697	0.95758					
mandibular right cuspid								
Caucasian	7.73421	0.61958	0.78713	0.8575	10.6596	3.265	2.01*	2.68**
Negro	8.59167	1.01190	1.00592					
mandibular right first bicuspid								
Caucasian	8.43158	0.77716	0.88156	0.5601	5.1451	2.268	2.01*	2.68
Negro	8.99167	0.92447	0.96150					
mandibular right second bicuspid								
Caucasian	9.46579	1.64479	1.28250		3.6076			
Negro	10.02500	2.07296	1.43978					

TABLE IV - E

OCCLUSAL RADIOGRAPHS

RACE	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
maxillary right second bicuspid								
Caucasian	7.26052	0.82072	0.90594	0.4978	10.8272	3.290	2.01*	2.68**
Negro	7.75833	0.73432	0.85692					
maxillary right first bicuspid								
Caucasian	7.35000	0.67338	0.82060	0.6333	14.3323	3.786	2.01*	2.68**
Negro	7.98333	0.73424	0.85688					
maxillary right cuspid								
Caucasian	8.33158	0.62377	0.78979	0.4351	4.2965	0.4351	2.01*	2.68**
Negro	8.76667	0.94060	0.96895					
maxillary left cuspid								
Caucasian	8.26316	0.70747	0.84111	0.4852	6.3676	2.523	2.01*	2.68
Negro	8.75833	0.56356	0.75071					
maxillary left first bicuspid								
Caucasian	7.45789	0.47636	0.69019	0.5671	10.1035	3.179	2.01*	2.68**
Negro	8.02500	0.88614	0.94135					
maxillary left second bicuspid								
Caucasian	7.31579	0.58223	0.76304	0.5175	11.0027	3.317	2.01*	2.68**
Negro	7.83333	0.90455	0.95108					

TABLE IV - F

OCCLUSAL RADIOGRAPHS

RACE	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
mandibular left second bicuspid								
Caucasian	8.03947	0.82524	0.90842	0.5689	4.8548	2.203	2.01*	2.68
Negro	8.60833	1.01553	1.00774					
mandibular left first bicuspid								
Caucasian	7.49210	0.72726	0.85280	0.4246	4.2415	2.059	2.01*	2.68
Negro	7.91667	1.41667	1.19023					
mandibular left cuspid								
Caucasian	7.5237	0.65366	0.80849		3.6812			
Negro	7.9833	1.33424	1.15509					
mandibular right cuspid								
Caucasian	7.60526	0.62760	0.79220	0.7614	8.5550	2.925	2.01*	2.68**
Negro	8.36667	1.04667	1.02307					
mandibular right first bicuspid								
Caucasian	7.48684	0.71332	0.84458	0.7382	12.2917	3.506	2.01*	2.68**
Negro	8.22500	1.23113	1.10957					
mandibular right second bicuspid								
Caucasian	7.97632	0.78330	0.88505		2.8346			
Negro	8.38333	1.19242	1.09199					

TABLE IV - G

PERIAPICAL RADIOGRAPHS

RACE	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
maxillary right second bicuspid								
Caucasian	7.44474	0.70223	0.83499		3.0589			
Negro	7.73333	0.76000	0.87178					
maxillary right first bicuspid								
Caucasian	7.47105	0.63411	0.79632	0.5039	11.6782	3.417	2.01*	2.68**
Negro	7.97500	0.74295	0.86195					
maxillary right cuspid								
Caucasian	8.31052	0.62661	0.79158		1.9095			
Negro	8.56667	1.09333	1.04562					
maxillary left cuspid								
Caucasian	8.25526	0.70740	0.84107		3.4125			
Negro	8.57500	0.74023	0.86036					
maxillary left first bicuspid								
Caucasian	7.57895	0.42205	0.64965	0.6627	14.5965	3.821	2.01*	2.68**
Negro	8.24167	0.76008	0.87182					
maxillary left second bicuspid								
Caucasian	7.50000	0.43486	0.65944	0.3750	5.3430	2.311	2.01*	2.68
Negro	7.87500	0.85568	0.92503					

TABLE IV - H

PERIAPICAL RADIOGRAPHS

RACE	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
mandibular left second bicuspid								
Caucasian	7.99999	0.85757	0.92605		0.5451			
Negro	8.14167	1.60098	1.26530					
mandibular left first bicuspid								
Caucasian	7.63158	0.65602	0.80995	0.5601	5.1760	2.275	2.01*	2.68
Negro	8.19167	0.92417	0.96133					
mandibular left cuspid								
Caucasian	7.22894	0.78430	0.88561	0.6044	12.8292	3.582	2.01*	2.68**
Negro	7.83333	1.57152	1.25360					
mandibular right cuspid								
Caucasian	7.32105	0.76586	0.87513	0.6623	11.4025	3.377	2.01*	2.68**
Negro	7.98333	1.36030	1.16632					
mandibular right first bicuspid								
Caucasian	7.68684	0.57386	0.75753	0.6715	12.6593	3.558	2.01*	2.68**
Negro	8.35833	1.08568	1.04196					
mandibular right second bicuspid								
Caucasian	7.93421	0.82518	0.90840		3.3427			
Negro	8.29167	1.31659	1.14742					

TABLE V

TABLE V - A

SUMMARY OF THE MEANS, VARIANCES, AND SIGNIFICANCE OF DIFFERENCES OF THE MESIAL-DISTAL DIAMETERS OF THE UNERUPTED TEETH AS OBSERVED BETWEEN SEXES BY FOUR RADIOGRAPHIC METHODS

EXPERIMENTAL PANOREX METHOD

SEX	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
maxillary right second bicuspid								
Male	8.06956	0.73858	0.89541	0.5029	5.1444	2.268	2.01*	2.68
Female	7.56667	0.50231	0.70874					
maxillary right first bicuspid								
Male	8.05652	0.87075	0.93314	0.5084	4.7432	2.178	2.01*	2.68
Female	7.54815	0.51259	0.71596					
maxillary right cuspid								
Male	8.94782	0.71170	0.84362	0.7589	11.8311	3.440	2.01*	2.68**
Female	8.18889	0.51410	0.71700					
maxillary left cuspid								
Male	8.74783	0.80625	0.89791	0.5330	4.9800	2.232	2.01*	2.68
Female	8.21481	0.62593	0.79115					
maxillary left first bicuspid								
Male	8.12174	0.60451	0.65837	0.4180	4.2405	2.059	2.01*	2.68
Female	7.70370	0.43345	0.77750					
maxillary left second bicuspid								
Male	8.04348	0.45711	0.67610		1.0088			
Female	7.85185	0.44798	0.66931					

TABLE V - B

EXPERIMENTAL PANOREX

SEX	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
mandibular left second bicuspid								
Male	8.82174	1.04269	1.02112	0.5106	4.2498	2.061	2.03*	2.72
Female	8.31111	0.43256	0.65770					
mandibular left first bicuspid								
Male	8.40000	1.02455	1.01219	0.6185	6.4048	2.531	2.03*	2.72
Female	7.78148	0.41003	0.64033					
mandibular left cuspid								
Male	8.37391	1.03565	1.01767	0.9850	16.9116	4.112	2.04*	2.73**
Female	7.38889	0.33334	0.57735					
mandibular right cuspid								
Male	8.48261	0.83423	0.91336	1.0715	24.1102	4.910	2.03*	2.73**
Female	7.41111	0.30641	0.55354					
mandibular right first bicuspid								
Male	8.59565	0.65589	0.80987	0.8549	16.4458	4.055	2.01*	2.68**
Female	7.74074	0.46405	0.68121					
mandibular right second bicuspid								
Male	8.89130	0.76901	0.87693	0.6061	7.8581	2.803	2.01*	2.68**
Female	8.28519	0.42131	0.64908					

TABLE V - C

STANDARD PANOREX

SEX	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
maxillary right second bicuspid								
Male	9.55217	3.03662	1.74260		1.8899			
Female	9.15556	3.12397	1.76748					
maxillary right first bicuspid								
Male	9.08696	1.98081	1.40741		0.6351			
Female	8.88519	2.36902	1.53916					
maxillary right cuspid								
Male	8.37826	1.05084	1.02511		1.6084			
Female	8.12963	0.51775	0.71955					
maxillary left cuspid								
Male	8.33043	0.98838	0.99417		0.0001			
Female	8.32963	0.63962	0.79976					
maxillary first bicuspid								
Male	8.90000	1.23773	1.11253		1.4132			
Female	9.14443	2.58901	1.60904					
maxillary left second bicuspid								
Male	9.22609	1.91925	1.38537		0.1199			
Female	9.30741	2.64811	1.62730					

TABLE V - D

STANDARD PANOREX

SEX	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
mandibular left second bicuspid								
Male	9.72174	1.88951	1.37459		3.1378			
Female	9.30741	1.46335	1.20969					
mandibular left first bicuspid								
Male	8.61304	1.07199	1.03537		0.9043			
Female	8.39630	0.80256	0.89586					
mandibular left cuspid								
Male	8.33044	1.03763	1.01864	0.7193	8.7169	2.952	2.03*	2.73**
Female	7.61111	0.38462	0.62017					
mandibular right cuspid								
Male	8.34348	0.85447	0.92437	0.7472	11.2065	3.348	2.03*	2.72**
Female	7.59630	0.34203	0.58483					
mandibular right first bicuspid								
Male	8.83478	0.71567	0.84597	0.4977	5.5790	2.362	2.01*	2.68
Female	8.33704	0.83329	0.91285					
mandibular right second bicuspid								
Male	9.87826	1.78737	1.33693	0.5153	4.2212	2.055	2.01*	2.68
Female	9.36296	1.62759	1.27577					

TABLE V - E

OCCLUSAL RADIOGRAPHS

SEX	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
maxillary right second bicuspid								
Males	7.51304	1.06237	1.03071		3.1400			
Females	7.26667	0.59577	0.77186					
maxillary right first bicuspid								
Males	7.71304	0.99409	0.99704	0.3908	6.4984	2.549	2.01*	2.68
Females	7.32222	0.56559	0.75206					
maxillary right cuspid								
Males	8.68260	0.78524	0.88614	0.4567	6.7485	2.598	2.01*	2.68
Females	8.22593	0.51553	0.71800					
maxillary left cuspid								
Males	8.64348	0.81763	0.90423	0.4842	8.6384	2.939	2.01*	2.68**
Females	8.15926	0.62913	0.79318					
maxillary left first bicuspid								
Males	7.76087	0.74066	0.86061		3.6305			
Females	7.45185	0.49932	0.70662					
maxillary left second bicuspid								
Males	7.51739	0.74646	0.86398		0.9536			
Females	7.37407	0.68503	0.82766					

TABLE V - F

OCCLUSAL RADIOGRAPHS

SEX	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
mandibular left second bicuspid								
Males	8.36957	1.25644	1.12091		1.7338			
Females	8.01111	0.52603	0.72528					
mandibular left first bicuspid								
Males	7.73478	1.48717	1.21949		0.8142			
Females	7.47407	0.50816	0.71286					
mandibular left cuspid								
Males	7.83913	1.33464	1.15527		2.0451			
Females	7.45926	0.33848	0.58179					
mandibular right cuspid								
Males	8.18696	0.92561	0.96209	0.7388	10.5690	3.251	2.04*	2.73**
Females	7.44815	0.30784	0.55483					
mandibular right first bicuspid								
Males	7.93913	1.10650	1.05190	0.5095	7.317	2.705	2.01*	2.68**
Females	7.42963	0.56456	0.75137					
mandibular right second bicuspid								
Males	8.22174	1.23771	1.11253		1.0145			
Females	7.94815	0.53927	0.73435					

TABLE V - G

PERIAPICAL RADIOGRAPHS

SEX	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
maxillary right second bicuspid								
Males	7.63913	0.93227	0.96554		2.6650			
Females	7.40740	0.52865	0.72708					
maxillary right first bicuspid								
Males	7.68670	1.01354	1.00674		1.6097			
Females	7.51111	0.51402	0.71695					
maxillary right cuspid								
Males	8.50434	0.91731	0.95776		2.4044			
Females	8.25926	0.51925	0.72059					
maxillary left cuspid								
Males	8.51304	0.86387	0.92945	0.3353	5.2964	2.301	2.01*	2.68
Females	8.17778	0.62735	0.79205					
maxillary left first bicuspid								
Males	7.92174	0.64632	0.80394	0.3403	4.3853	2.094	2.01*	2.68
Females	7.58148	0.44896	0.67004					
maxillary left second bicuspid								
Males	7.68260	0.59326	0.77023		1.4098			
Females	7.51111	0.56854	0.75402					

TABLE V - H

PERIAPICAL RADIOGRAPHS

SEX	MEAN	VARIANCE	STD. DEV.	DIFF. OF MEANS	F VALUE	T-VALUE	CRITICAL VALUE .05	.01
mandibular left second bicuspid								
Males	8.09130	1.60047	1.26509		0.1257			
Females	7.98519	0.54288	0.73680					
mandibular left first bicuspid								
Males	7.86957	1.31870	1.14834		0.5044			
Females	7.67778	0.42120	0.06489					
mandibular left cuspid								
Males	7.56957	1.71203	1.30845		1.4897			
Females	7.20740	0.36754	0.60625					
mandibular right cuspid								
Males	7.68696	1.49607	1.22314		1.9117			
Females	7.30370	0.31839	0.36426					
mandibular right first bicuspid								
Males	8.05217	0.96468	0.98218	0.3781	4.7537	2.180	2.01*	2.68
Females	7.67407	0.46866	0.68459					
mandibular right second bicuspid								
Males	8.21304	1.24996	1.11802	0.3575	4.6708	2.161	2.01*	2.68
Females	7.85556	0.61299	0.78294					

FIGURES

Figure 1.

Diagramatic representation of the geometric relationships of a patient positioned for a Panorex radiograph.

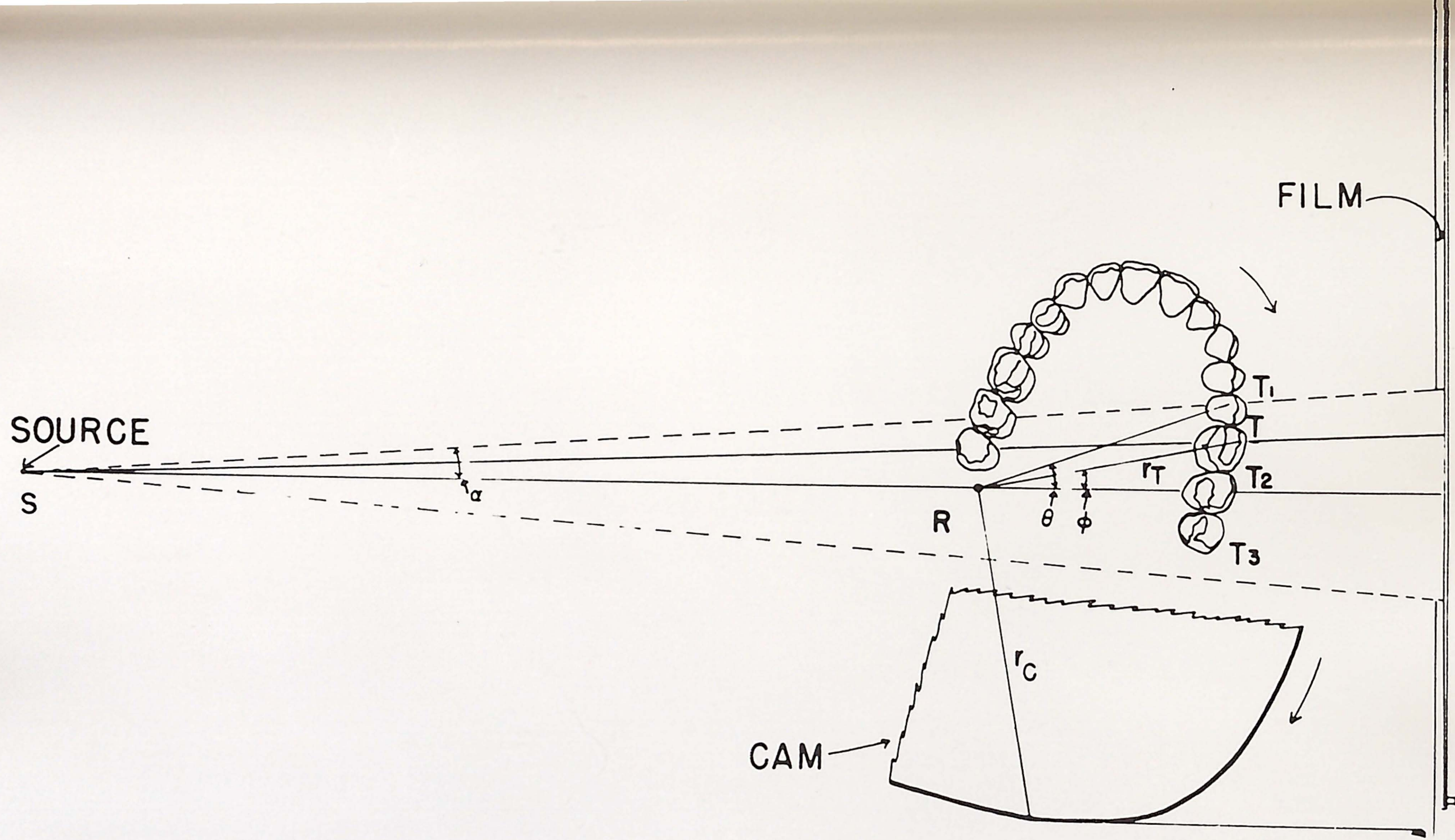

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Figure 2.

Plexiglas grid with rotational arcs of varying distances from the center of rotation.

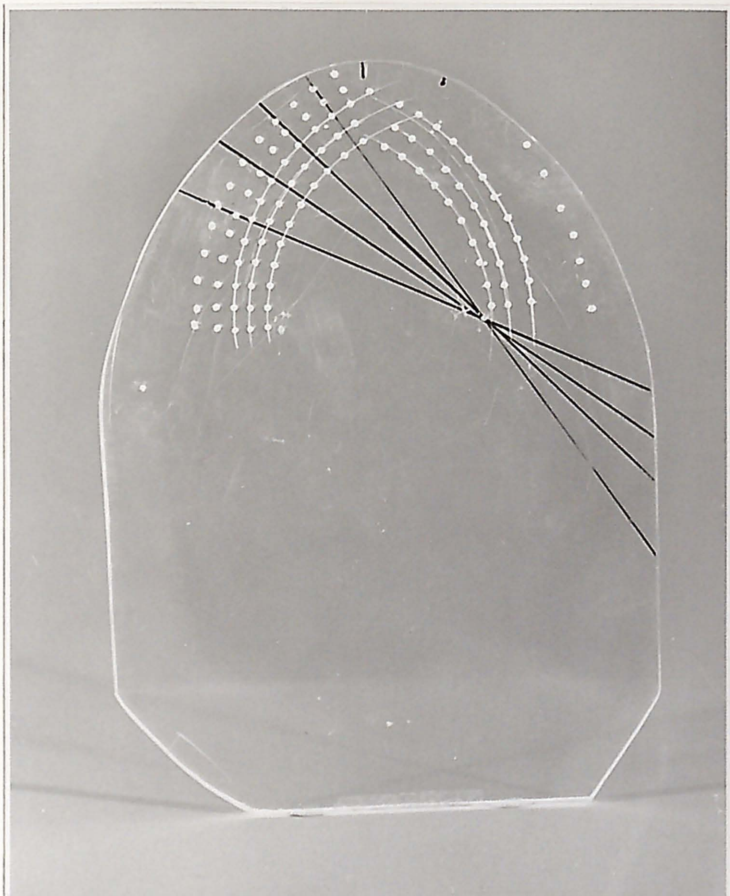

Figure 3.

Relationship of the template to the outer rim of the intraoral positioning device.

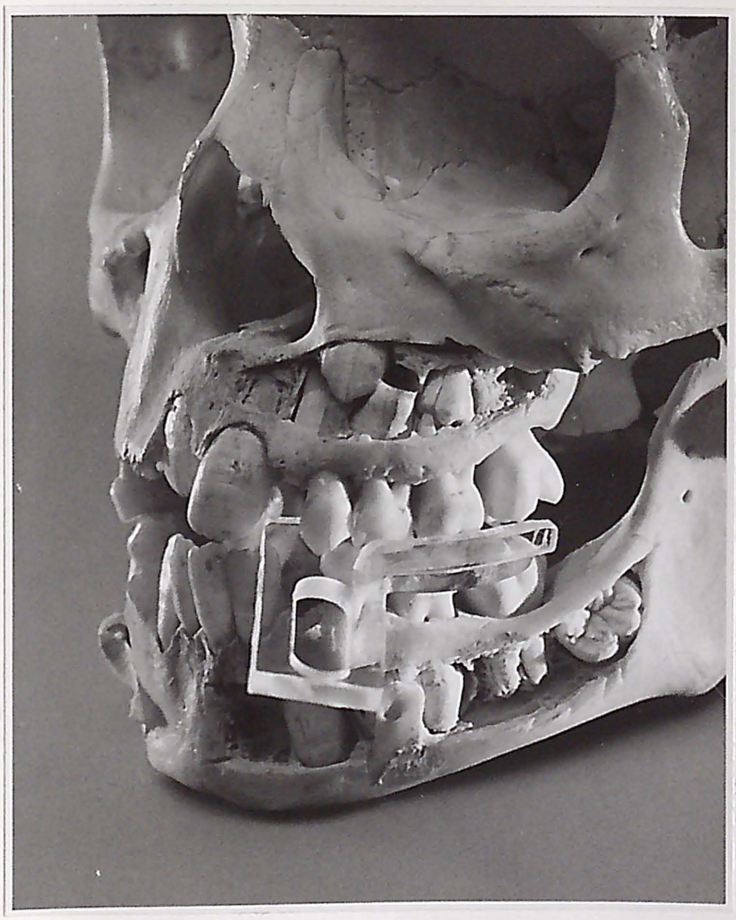

Figure 4.

The experimental cephalostat.

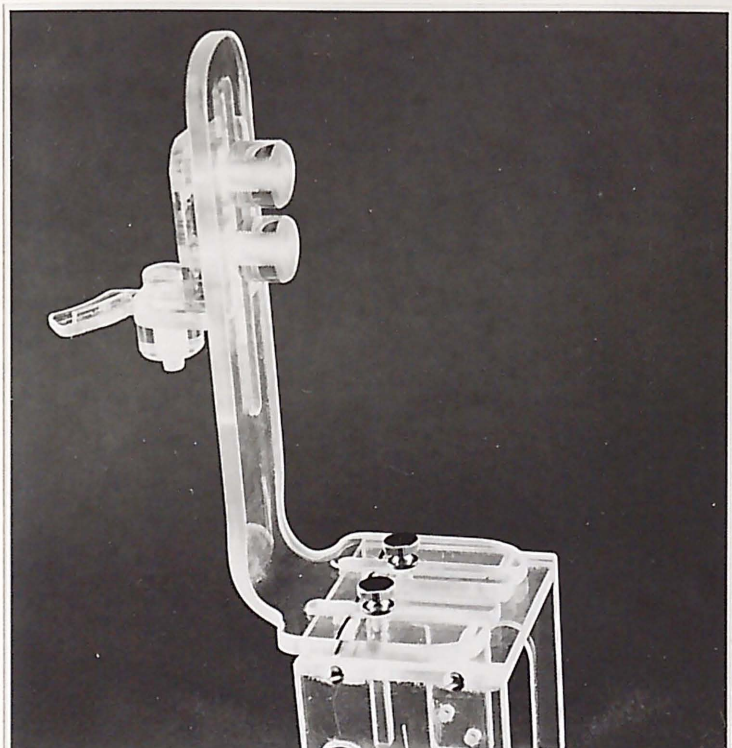

Figure 5.

Intraoral positioning devices. The left template demonstrates the metallic inserts.

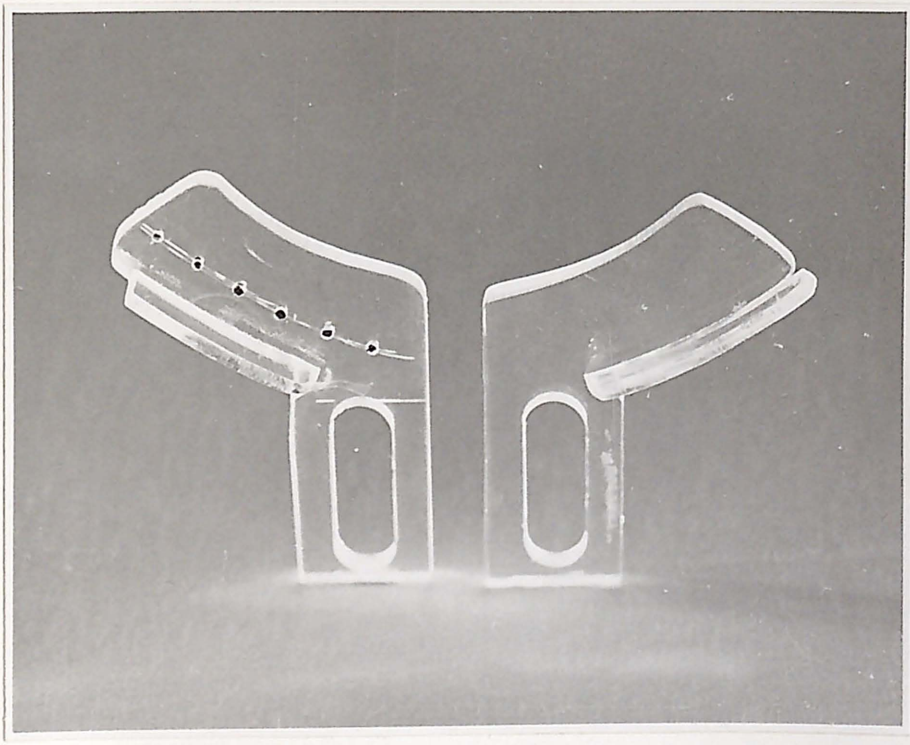

Figure 6.

Eccentric position of patient for exposure of the experimental Panorex.


PANCENTRIC

Figure 7.

Left and right portions of the experimental Panorex radiographs approximated.

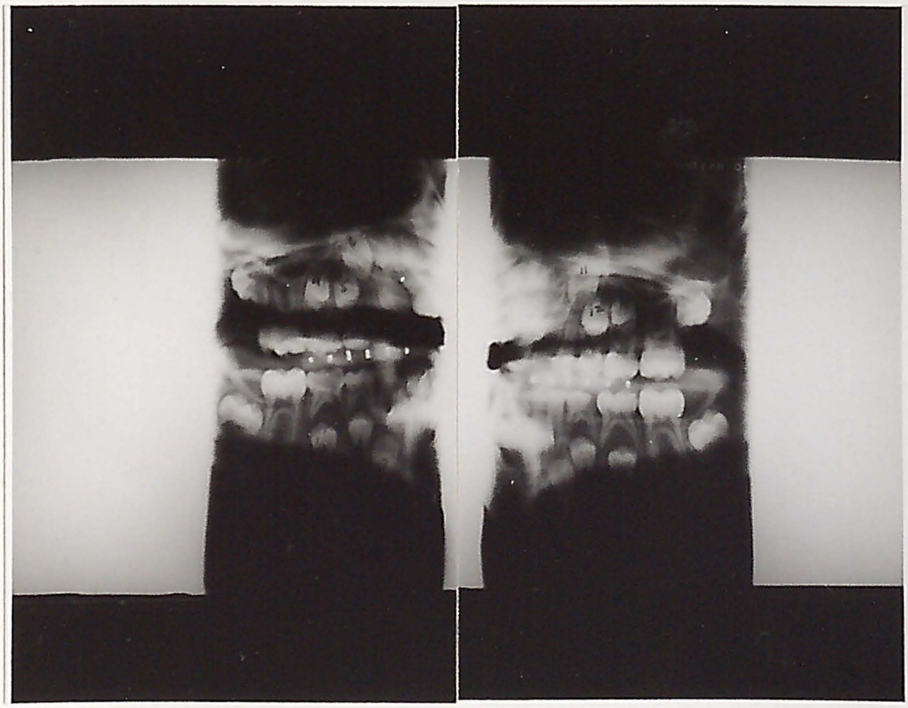

Figure 8.

Data Form.

PATIENT'S NAME______________________________ AGE______ RACE______

ADDRESS____________________________________ PHONE______ SEX______

Examiner____________

TOOTH NO.	Exp. Panorex	Panorex	Occlusal Film	Periapical Film	Moyer's Total/Quad.	Four Mand. Incisors	Actual Measurements
4							
5							
6							
Tot.							
11							
12							
13							
Tot.							
20							
21							
22							
Tot.							
27							
28							
29							
Tot.							
23							
24							
25							
26							
Tot.							
A							
B							
C							
H							
I							
J							
K							
L							
M							
R							
S							
T							

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Figure 9.

Maxillary occlusal radiographs.

Figure 10.

Mandibular occlusal radiographs.

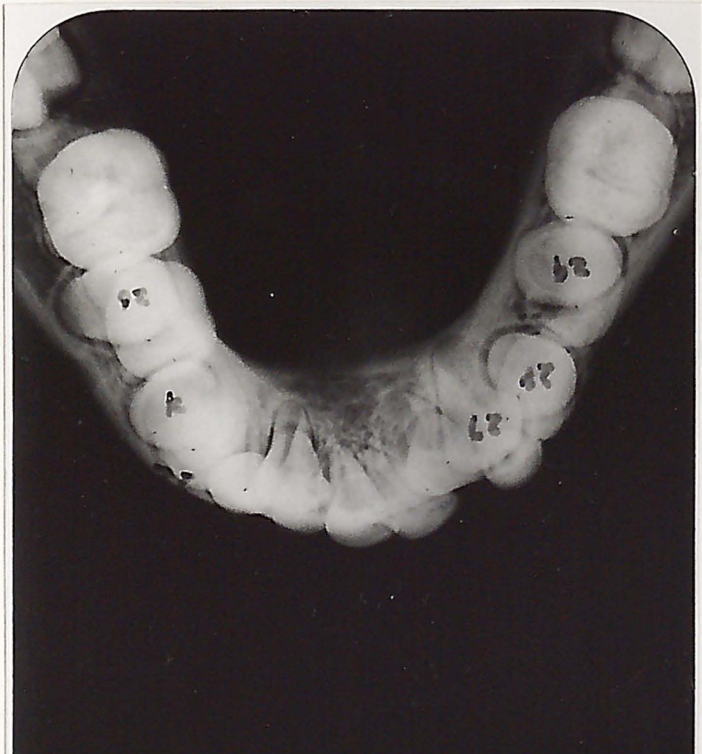


Figure 11.

Periapical radiographs.

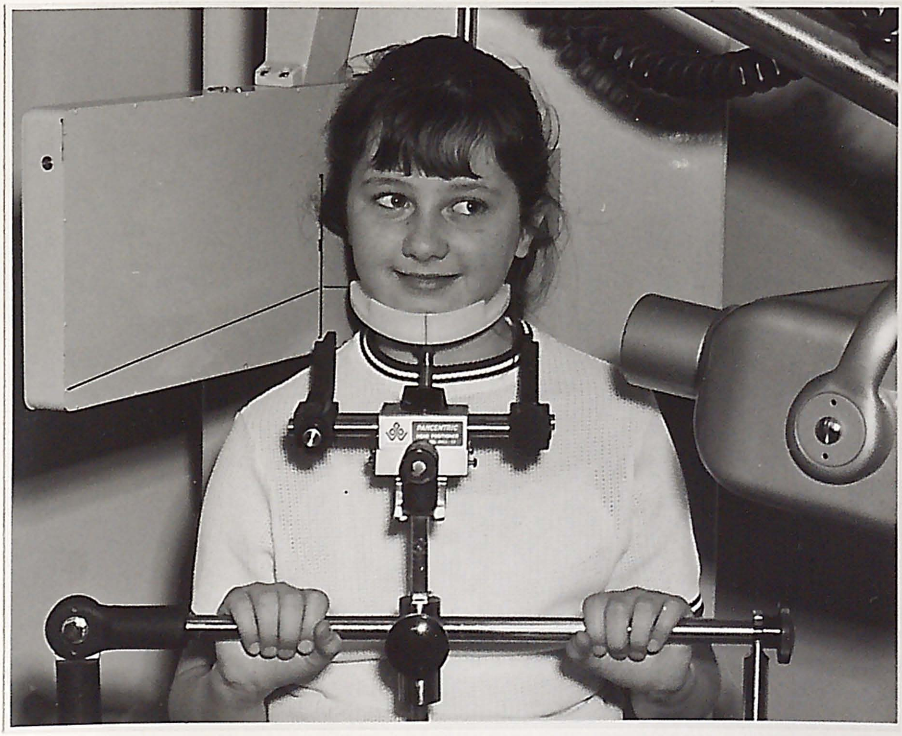

13
12
11
KS

Figure 12.

Standard Panorex radiograph.

Figure 13.

Patient positioning for a standard Panorex.



DISCUSSION

Achieving accuracy and reproducibility in assessing arch length and tooth mass has always posed a problem for the clinician. The purpose of this study was to devise a panoramic radiographic technique and examine its usefulness in quantitatively evaluating the mesial-distal diameters of unerupted teeth.

Essential to the experimental procedure was the continuous direction of the central ray perpendicular to an imaginary line in space. If an object or series of objects were placed coincident with this imaginary line or plane in space, horizontal distortion would be minimized.

Hypothetically, a direct measurement of the resultant image from the film would represent a consistently true dimension of the mesial-distal diameter of the unerupted tooth or at least be a uniformly magnified image.

The predetermined plane of minimal distortion was marked with a portion of plexiglass that had been formed to the shape of the dental arch, and attached to the chin rest of the Panorex. Radiographs of fifty patients were made using the plexiglass guide to aid in positioning of the dental quadrants so that the teeth would lie in a plane which coincided with this imaginary line.

The accuracy of the experimental method in reproducing the mesial-distal diameters of teeth was determined relative to other radiographic and statistical methods, as absolute dimensional values of unerupted teeth are not obtainable in a cross-sectional study. Thus the radiographic examination included periapical, occlusal, and standard Panorex radiographs.

Kite and others demonstrated greater image distortion in the posterior segments of the dental arch than in the anterior segments. They noted that the anterior distortion could be negative in the incisor area and range to a greatest increase in magnification in the second molar area. Kite and Updegrave demonstrated a 6 -17 per cent and 7 -12 per cent horizontal magnification, respectively, whereas Christen noted a five per cent reduction in the size of the image of the premolars.

In this study there was a greater range of magnification of the images of the teeth, as recorded with the standard Panorex, than had previously been noted. There was a horizontal increase in the image size of 0 to 24.3 per cent in the bicuspid area, with the Panorex exposed according to the manufacturer's recommendations, compared to measurements of the image determined from periapical radiographs.

In contrast, a 0.9 to 6.8 per cent magnification occurred with the Panorex made with the experimental method and compared similarly to periapicals. More magnification occurred with the more posterior second bicuspid than the more anterior cuspid. The magnification of the second bicuspid, the first bicuspid, and the cuspid was 3.8, 2.5, and 2.2 per cent, respectively, compared to the periapical dimension. The per cent difference from the mean of the maxillary right second bicuspid, first bicuspid, and cuspid was 24.3, 18.4, and 2.0 per cent, respectively, in a similar comparison but with the Panorex made by the standard method.

In spite of the reduction in magnification achieved by positioning the patient closer to the film, the dimensions of the second bicuspids were significantly different from periapical dimensions. Such a comparison is only relative and does not assume that measurements recorded from peripaical radiographs are absolute, for this certainly is not true. However, comparisons with the periapical films, an accepted method of obtaining the dimensions of unerupted teeth, are convenient and although such comparisons invite error, they place results in perspective.

Other limitations were imposed in the study. Uncertainty existed regarding the measurements of accuracy and reproducibility of the radiographic material by two examiners working independently. The experimental method required a patient position which was at the outer edge of the focal trough, which contributed to an image which had less horizontal magnification but lacked sharpness of detail.

It was interesting, although consistent with the findings of Brown,[41] that the area in focus or focal trough was considerably wider than had been previously reported by several authors and appreciably greater than specified by the manufacturer. This plane originally was determined by Kite to be one-half to three-fourths of an inch wide or 1.3 to 1.9 cm. wide. It was found that a patient could be positioned sixty-three millimeters from the axis of rotation and a recognizable image of the teeth could still be recorded.

The degree of magnification and the consistent overlapping of images of the teeth on the standard Panorex resulted in measuring difficulties in spite of specific measuring criteria. However, significant measuring differences were not observed between the two examiners and the criteria and instrument of measurement were considered adequate.

An important aspect of radiographic technique is standardization of the procedure so that results are reproducible by different operators. Certainly a cephalostat has been demonstrated as being a good instrument in standardization procedures. Such an instrument was constructed to aid in patient positioning but the design had limitations. As a result of the required rotation of the head, the chin support of the Pancentric head positioner impinged upon the necks of some individuals, resulting in slight movement of the teeth away from the outer rim of the intraoral support during the excursion of the machine. An increased object-film distance would result for these subjects. The plexiglass material from which the cephalostat was made also lacked total rigidity and the patient could slightly bend the main support.

Perhaps the major source of error was in the comparisons of the dimensions of the unerupted teeth obtained from the experimental method with other radiographic methods which also have inherent weaknesses and inaccuracies. Reliable comparisons could have been made only after the permanent teeth had erupted and a direct measurement had been obtained. A cross sectional study is justified, however, in demonstrating similarities and differences through comparisons of accepted methods with other methods, so long as it is recognized that such comparisons invite error.

Certain inherent properties of the Panorex result in error. Many authors have observed variable distortions resulting from the fact that the machine was not properly centered in relation to the patient. That distortion was largely avoided in the present study by designing the cephalostat in accordance with the centers of rotation present at the time the cephalostat was constructed, instead of the theoretical centers.

There is always a question as to whether the study sample is representative of the general population. The variables of patient age, sex, race, size, individual arch form, and location of the unerupted teeth in relation to the film cannot all really be accounted for in a lockstep procedure. If one is cognizant of all the variables, it obviously is impossible to pass a central ray perpendicularly through a series of anatomic structures at every instant of the exposure time for all patients. A Panorex design which has an infinite number of rotational axes or can move the patient continuously to a single rotational axis is feasible and is the only like means of standardizing inherent error.

Consequently, a single change in a patient's position for a Panorex to decrease error can be only partially successful in alleviating distortion of a series of anatomic structures. Ideally, a repositioning of the patient before recording each tooth would give the least magnification, but would be impractical in the clinical situation.

The results of this study show that the technique described may be a practical method of estimating tooth mass in a survey of a large population or where intraoral film placement is impractical. The results are in terms of averages, which tend to obscure individual differences as well as the character of the variation. This accounts in part for the difficulties which the dentist encounters in practice when he attempts to study patients as individuals rather than as members of a group.

Wide variations in the averages of the measurements and the F ratios do not render the experimental technique in its present form applicable on an individual basis, even with a standardization factor. Essentially identical dimensions for an unerupted tooth were obtained by the experimental method, periapical radiograph, and Moyer's table for some individuals in the group, but other teeth or groups of teeth demonstrated a dimensional difference of two millimeters for a single tooth. The average difference of 20.5% reduction in magnification was observed for the maxillary right second bicuspid between the two Panorex methods when compared to the periapical film. The results were reversed to a lesser degree in a similar comparison with the cuspid. The mandibular cuspids consistently appeared rotated in the experimental film and the greatest mesial-distal diameter was not recorded in every case.

The horizontal distortion of the mesial-distal dimension of unerupted teeth can be dramatically reduced by positioning the patient to a simulated dental arch form. Statistically, the average dimensions obtained by the experimental panoramic method were very similar to those obtained by intraoral radiographic methods.

With improvements in design of the cephalostat used in this study, along with a Panorex design which would allow greater flexibility and maneuverability of operation, further study might demonstrate that a direct and highly accurate measurement of an anatomic structure such as a tooth can be reliably obtained and used in the mixed dentition analysis.

SUMMARY AND CONCLUSIONS

Applications of plane surface radiographic principles to the variations peculiar to curvilinear radiography were tested to determine the feasibility of producing a dimensionally accurate image with the Panorex radiograph. Essential to the study was the orthoradial projection of the central ray through the object or objects in the focal trough. This was accomplished by positioning the head eccentrically so that the central ray would pass through the contact points of the cuspid and bicuspid teeth. The dental quadrant, at the same time, was positioned as close to the film as possible. A cephalostat was constructed to assist in accurate placement of the head.

Production of a dimensionally true image of the unerupted cuspids and bicuspids would permit the dentist to use the Panorex radiograph in assessing tooth mass for use in the mixed dentition analysis.

Accuracy of the experimental method was assessed by comparing the mesial-distal diameters as determined by the experimental method with various other radiographic methods, occlusal, periapical, and standard Panorex, and with Moyer's prediction chart.

From the data collected and analyzed, a consistent reduction in horizontal magnification occurred as compared to the Panorex film made according to the manufacturer's recommendations.

The wide variance in the averages of the measurements and the F ratios observed indicate that the technique in its present form does not produce results which are consistently accurate enough enough bo be applied to the analysis of arch length.

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ABSTRACT

PREDICTING THE MESIAL-DISTAL DIAMETERS OF TEETH WITH PANORAMIC RADIOGRAPHY

Paul E. Schneider

The purpose of this study was to determine the relative accuracy of a panoramic radiographic method in the determination of unerupted tooth mass.

Four types of radiographic films were made for each of fifty children. The diameters of the unerupted permanent cuspids and bicuspids were measured to compare and assess the degree of linear distortion between the types of radiographs when obtained under routine clinical conditions. The experimental Panorex film was made with the patient positioned eccentrically, but all other radiographic procedures used in this study followed the techniques recommended by the Indiana University School of Dentistry Department of Radiology.

The greatest mesial-distal dimensions of the unerupted permanent cuspids and bicuspids were recorded to the nearest 0.1 millimeter. The data were recorded on standard IBM punch cards and submitted for summation and statistical analysis to the Research Computation Center of Indiana University-Purdue University at Indianapolis.

Although magnification was reduced considerably, the experimental technique was demonstrated not to be of sufficient and consistent accuracy to be applicable in the determination of tooth mass for the mixed dentition analysis.